Integrated Transmodal Freight Infrastructure

(A look ahead to 2040 and beyond)

Table of Contents

INTRODUCTION *3*

SECTION 1 – FUNDING CONCEPT *5*

Section 1.1 Funding Framework **5**

Section 1.2 Funding Notes **6**

Section 1.3 Other Benefits **6**

SECTION 2 – WHAT IS INTERMODAL AND TRANSMODAL FREIGHT TRANSPORTATION AND CONTAINERIZATION *8*

Section 2.1 The Nature of Intermodalism **8**

Section 2.2 Forms of Intermodalism **12**

Section 2.3 Containerization **14**

Section 2.4 Advantages and Challenges of Containerization **19**

SECTION 3 – WHAT PROBLEMS AND SOLUTIONS EXIST FOR THE ADVENT OF TRANSMODAL TRANSPORTATION. *26*

SECTION 4 – WHAT NEXTGEN TRANSMODAL FREIGHT TRANSPORTS LOOKS LIKE *30*

Section 4.1: Non-hydrocarbon marine propulsion systems **31**

Section 4.2: High speed rail locomotives with non – hydrocarbon propulsion systems **37**

Notes 43

Conclusion 46

Section 4.3: Inland container on barge propulsion and operations **47**

Conclusion 55

Section 4.4: Nextgen concrete roadbeds **56**

Section 4.5: Non-hydrocarbon air freight concept **67**

CONCLUSION *76*

INTRODUCTION

This paper concerns the need for and represent an informed vision of integrated transmodal freight infrastructure circa 2040 and beyond. Bits, pieces, and parts of that need exist now. A partial example would be Amazon's delivery system. In this type of delivery system, Amazon would be a customer. Oddly enough, no one has ever integrated an end-to-end infrastructure model that seamlessly delivers goods globally from the manufacturers (or a mine) shipping dock to the consumer or enduser. Currently they always need several "pairs of hands" and their stacked margins that inevitably delay delivery and add excessive costs and use of resources that needn't be spent. By 2040 those delays and costs and their need for additional resources will be cost and time prohibitive and may also cause real societal harm by using resources that can't be replaced or reused.

This author wants to outline how to fund the cost to develop it, outline what an integrated transmodal freight infrastructure would "look" like and describe the mechanical prime movers inherent to it and some smaller details about what some of it can be driven upon. It is my firm belief that bringing an integrated transmodal freight model to life would help prevent societal and its' global economy real, lasting, and perhaps fatal harm. Saying that it also would be a strong contributor to slowing global climate change and its terrible effects could be inferred.

First an introduction about infrastructure and what it does. Infrastructure, such as roads, bridges, power grids and internet access are now required for any society to be successful. Further, we are citizens of the most globally advanced society with no qualification. Maintaining that superiority requires that we find new ways to fund and force infrastructure development through time with both little input and monies from government. Why little government involvement? Because government as its own structural entity changes through time as demographics and needs change. The need for infrastructure does not change but its needs do change. This author believes that government may well not have the will or focus to make such changes happen in any large meaningful way. Therefore, logically, how to keep infrastructure both functional and relevant through time offers some real challenges that must be addressed.

"Strength lies not in defense but in attack. Attack the problem"

Infrastructure can also be described as the backbone of society. Without continuous infrastructure development and support society either cannot exist, or it begins to fail. If, though, it had it and it fails without repair sufficient to keep it working societal failure can happen. This may seem counterintuitive, but it's not. Societal failure can be difficult to recover from, if that is even possible, if history teaches us anything. Infrastructure therefore requires funding and ongoing support that cannot be stopped. How we can do that is the subject of this simple paper which is now on its fifth revision.

You will also read ad nauseum about a novel type of power generation system that uses both oxygen and hydrogen gas mixed as a "fuels" then combusted to create an expanding gas to drive turbines that spin electrical generators. I advocate that system because those fuels are readily available locally in the air we breathe and the type of technology it requires to "make" them requires few moving parts and nearly no proprietary technology or special materials. Why that type of system is not more widespread would take another book full of intrigue like a spy / thriller novel. Suffice it to say, it is real and can be readily done.

Last, this research was completed during the Covid-19 pandemic. It reflects a continuation of my efforts to address climate change mitigation from a technology perspective. It was funded by a modest SBA PPP loan that was later forgiven. I needed that loan to keep the lights on while looking to continue my business or at least find other work. None of that effort worked because of the pandemic. But accordingly, I do think the contents herein belong to everyone because I accepted modest public funding.

SECTION 1 – FUNDING CONCEPT

Infrastructure projects can be funded from a tax source that has never been exploited:

Energy Consumption

Energy consumption is now being tracked and analyzed by the U.S. Energy Information Administration which is part of the U.S. Department of Energy.

Energy consumption is reported as units of "Btu consumed" and is usually reported in blocks of 1000 Btu.

Section 1.1 Funding Framework

- Energy Consumption tax would be collected as $0.01 / 1000 Btu "blocks" consumed or similar.
- Summed, the energy consumption tax would equal roughly $130 Billion USD / year.
- This tax would be collected daily from local / county / state and federal sources via a highly secured "cloud" connection.
- This tax "pool" would need to be protected from theft, money laundering, inflation or deflation or appropriation.
- Protection from these would require both cybersecurity and the tax pool funds converted to a "pool" of "coin" which could be expressed as dollars or another currency.
- A "coin" could or maybe should be a unique cryptocurrency encrypted by USA cybersecurity which may or may not be distinct from existing cybersecurity agencies.
- USA cybersecurity would also be funded from the "pool".
- Accruing the value of "coin" in the "pool" is important especially as energy consumption declines.
- Cryptocurrency for this "pool" would therefore have a finite or fixed number of "coins" available for distribution into qualified projects.
- Accepted and qualified projects would have "coins" converted to USD or other fiat monies to purchase goods and services for the "project".

- Incentives (some multiple ranging from small to large) would be offered and paid as incremental "coin" for projects that save "energy" both during construction and over its lifetime.
- Said incentives would be paid out both on an anticipated and incremental time basis.

Section 1.2 Funding Notes

- Security would need no oversight except cybercrime prevention.
- Coins increase in value as energy "savings" occur due to the limited number of coins.
- A small number of new coins can be created by "block chain mining" or as incentives realized for energy budget consumption reduction become realized.
- The total value of the coin "pool" would accrue rapidly and likely exceed some large $ amount in Yr1 let alone Yr10, which would likely be well over $1 Trillion USD.
- A sovereign cryptocurrency avoids inflation or deflation risks, acts of God, money laundering, or theft risk etc.
- Direct trading between this cryptocurrency and other sovereign currency would be forbidden in an exchange.
- The Agency or Firm as founder keeps a set minimum number of "coins". As coins are "added" or the pool value grows they can be converted to any other sovereign money either individually or as a block.
- Alternatively, the founding agency or government keeps a very small residual of the traded valuation of the coin pool, most likely on the order of 0.01% which would equal $10 billion / year or much more as the pool develops.

Section 1.3 Other Benefits

- Development of sufficient cybersecurity to ensure the integrity of the pool could be seen as infrastructure. This cybersecurity need not be limited to only uses pertaining to the pool.
- The advent of practical quantum computing by 2040 will support both the blockchain validation for coin valuation and trading but also cybersecurity if approached very cautiously.

- Energy transmission related infrastructure could be included or by extension it's cybersecurity and integrity.
- Water treatment and its distribution and food (although food would be a conceptual "stretch").
- Roads, bridges, dams, levees, traffic lights, toll booths etc would be funded.
- Also, nextgen data transmission networks (5G or later) could be funded and maybe should be funded since they seem to be "evergreen" since Moore's Law remains a "thing".
- Last and not least, IIF technology development will need initial venture monies to prove up non-hydrocarbon power generation for high-speed rail, aircraft, ships, and freight aircraft.

SECTION 2 – WHAT IS INTERMODAL AND TRANSMODAL FREIGHT TRANSPORTATION AND CONTAINERIZATION

As always, this author will use others' publications to explain concepts such as this. The content has been lightly edited for length.

This citation: **The geography of transport systems**, ISBN 9780367364632
Published May 26, 2020, by Routledge
480 Pages 140 B/W Illustrations

"Authors: Dr. Jean-Paul Rodrigue and Dr. Brian Slack

Intermodal transportation concerns the movements of passengers or freight from an origin to a destination relying on several modes of transportation. The container has become the dominant intermodal transport unit.

Section 2.1 The Nature of Intermodalism

Competition between modes has tended to produce transportation systems that were **segmented and un-integrated**; in their own "silos". Each mode, particularly the carriers that operated them, has sought to exploit its advantages in cost, service, reliability, and safety. Carriers try to gain market share and increase revenue by maximizing the line-haul under their control. All the modes saw the other modes as competitors and were viewed with suspicion and mistrust, often because under a different regulatory regime and competitive rules. The lack of integration between the modes was also accentuated by **public policy** that has frequently prevented companies from owning firms in other modes (as in the United States before deregulation) or has placed a mode under direct state monopoly control (as in Europe and East Asia). **Modalism** was also favored because of the technical difficulties of transferring goods from one mode to another, thereby incurring additional terminal costs and delays, mainly because the load unit needed to be changed, which is typical for bulk transportation.

Since the 1960s, major efforts have been made to integrate separate transport systems through intermodalism, which took place in several stages, first with the setting of maritime networks, which then better connected with inland networks. From a functional and operational perspective, three components are involved in intermodalism:

***Intermodal transportation**. The movements of passengers or freight from an origin to a destination relying on several modes of transportation. Each carrier is issuing its own ticket (passengers) or contract (freight). Transfers from one mode of transport to another are commonly taking place at a specifically designed terminal. Therefore, intermodal transportation refers to an exchange of passengers or freight between two transportation modes. The term has become more commonly used for freight and container transportation across a sequence of modes. In North America, the term intermodal is also used to refer to containerized rail transportation.*

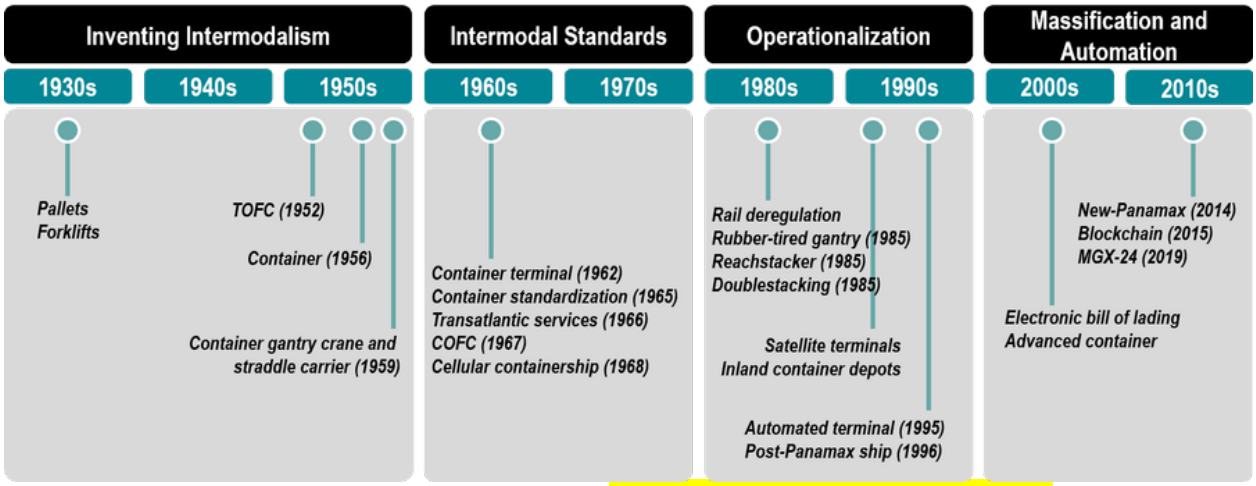
***Multi-modal transportation**. The movements of passengers or freight from an origin to a destination relying on several modes of transportation using one ticket (passengers) or contract (freight). Technically the same as intermodal transportation but represents an evolution requiring a higher level of integration between the actors involved such as carriers and terminal operators.*

***Transmodal transportation**. The movements of passengers or freight within the same mode of transportation. Although "pure" transmodal transportation rarely exists and an intermodal operation is often required (e.g., ship to dockside to ship), the purpose is to ensure continuity within the same modal network.*

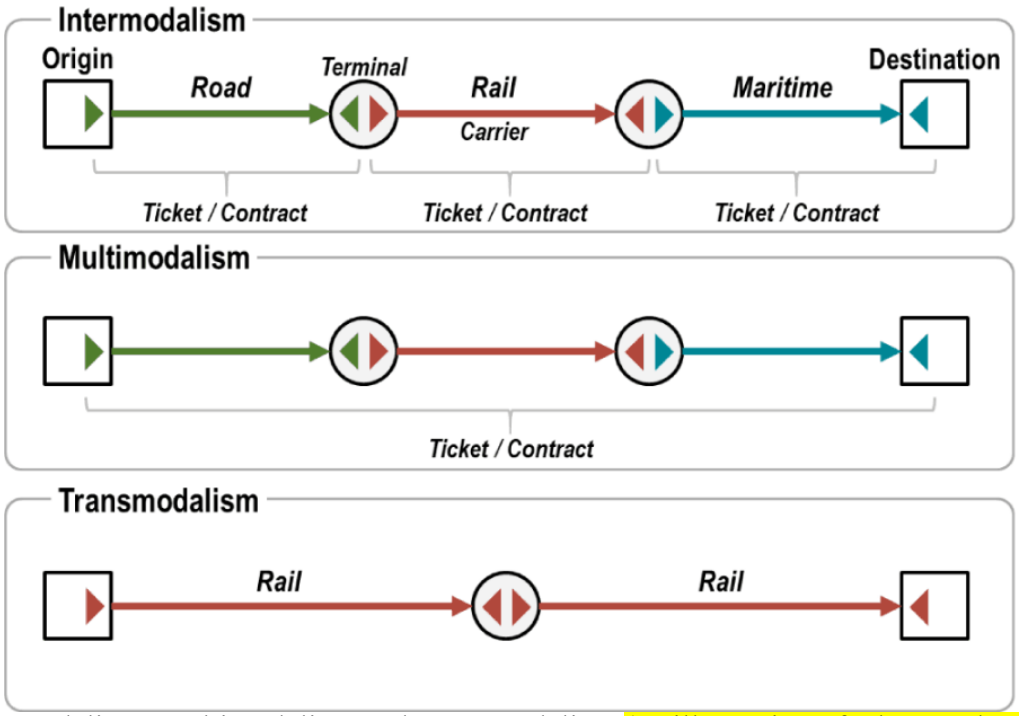
With intermodal transportation, what initially began as improving the productivity of shipping evolved into an integrated supply chain management system across modes and the development of multi-modal transportation networks.

***Multi-modal transportation network**. A logistically linked system using two or more transport modes with a single rate. Modes have common handling characteristics, permitting freight (or people) to be transferred between modes during a movement between an origin and a destination. For freight, it also implies that the cargo does not need to be handled, just the load unit, such as a pallet or a container.*

The next section contains several graphic tables and charts that illustrate what is considered state of the art in IIF and what should be coming as Transmodal Freight if it progresses with proper funding – this author.



Major Steps in Intermodal Integration (a historical timeline – this author).



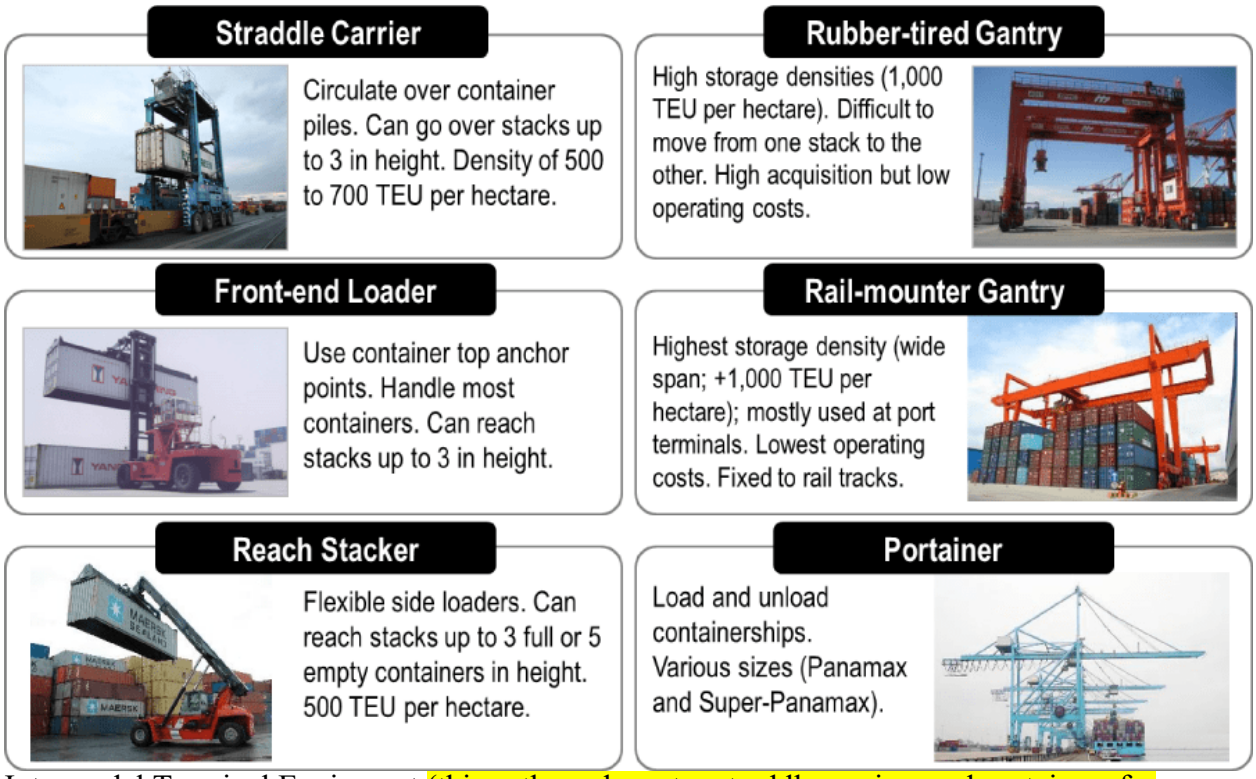
Intermodalism, Multimodalism and Transmodalism (an illustration of what can happen with a 10%+ plus reduction in freight cost and time to delivery by using the transmodal freight concept – this author).

Intermodalism involves using at least two different modes in a trip from an origin to a destination through an intermodal transport chain, which permits the integration of several transportation networks. Intermodality enhances the economic performance of a transport chain by using modes in the most productive manner. Thus, the line-haul economies of rail may be exploited for long distances, with the efficiency of trucks providing flexible local pick up and

deliveries. The key is that the entire trip is seen as a whole, rather than as a series of legs, each marked by an individual operation with separate sets of documentation and rates. This system is organized around the following conditions:

- The **nature and quantity** of transported cargo. Intermodal transportation is usually suitable for intermediate and finished goods in load units of less than 25 tons. The mode with the lowest capacity usually defines the intermodal load unit. As such, intermodal transportation is constrained by the trucking load unit (hence the need for standardized containers – this author).
- The **sequence of transportation modes** being used. Intermodal transportation is organized as a sequence of modes, often known as an intermodal transport chain. **The dominant modes supporting intermodalism are trucking, rail, barges, and maritime** (which are covered individually in my portion of this report – this author). Air transportation usually only require intermodalism (trucking) for its "first and last miles" and not used in combination with other modes. Additionally, load units used by air transportation are not readily convertible with other modes.
- The **origins and destinations**. Distances play an important role as the longer the distance, the more likely an intermodal transport chain will be used. Distances above 500 km (longer than one day of trucking) usually require intermodal transportation.
- The **value of the cargo**. Suitable for intermediate cargo values. Low and high-value shipments are usually less suitable for intermodal transportation. High-value shipments will tend to use the most direct options (such as air cargo), while low-value shipments are usually point-to-point and relying on one mode such as rail or maritime.
- The **frequency of shipments**. Intermodalism functions well when cargo flows need to be continuous and in similar quantities.

Intermodal transportation is capital intensive, implying that it requires specialized equipment to transfer cargo from one mode to the other.


Straddle Carrier
Circulate over container piles. Can go over stacks up to 3 in height. Density of 500 to 700 TEU per hectare.
Rubber-tired Gantry
High storage densities (1,000 TEU per hectare). Difficult to move from one stack to the other. High acquisition but low operating costs.
Front-end Loader
Use container top anchor points. Handle most containers. Can reach stacks up to 3 in height.
Rail-mounter Gantry
Highest storage density (wide span; +1,000 TEU per hectare); mostly used at port terminals. Lowest operating costs. Fixed to rail tracks.
Reach Stacker
Flexible side loaders. Can reach stacks up to 3 full or 5 empty containers in height. 500 TEU per hectare.
Portainer
Load and unload containerships. Various sizes (Panamax and Super-Panamax).

Intermodal Terminal Equipment (this author advocates straddle carriers and portainers for transmodal freight).

Section 2.2 Forms of Intermodalism

Intermodalism originated in maritime transportation, with the development of the container in the late 1960s and has since spread to integrate other modes. It is not surprising that the maritime sector should have been the first mode to pursue containerization. It was the mode most constrained by the time taken to load and unload vessels. A conventional breakbulk cargo ship could spend as much time in a port as it did at sea. Breakbulk cargoes were handled by stevedores who used ad-hoc means to load, unload, and move cargoes between the ships, piers, and warehouses. There were no standard forms of cargo handling and equipment. Containerization permits the mechanized handling of cargoes of diverse types and dimensions placed into boxes of standard sizes. In this way, goods that might have taken days to be loaded or unloaded from a ship can now be handled in a matter of minutes.

The emergence of intermodalism has been brought about in part by technology and requires **management units** for freight, such as containers, swap bodies, pallets, or semi-trailers. In the past, pallets were a common management unit,

but their relatively small size and lack of a protective frame made their intermodal handling labor-intensive and prone to damage or theft. Better techniques and management units for transferring freight from one mode to another have facilitated intermodal transfers. Early examples include piggyback (TOFC: Trailers on Flat Cars), where truck trailers are placed on rail cars, and LASH (lighter aboard ship), where river barges are placed directly on-board sea-going ships. A unique form of an intermodal unit has been developed in the rail industry, particularly in the United States, where there is sufficient volume. A roadrailer is essentially a road trailer that can also roll-on rail tracks. It is unlike the TOFC (piggyback) system that requires the trailer to be lifted onto to rail flatcar. Here the rail bogies may be part of the trailer unit or be attached in the railway yard. The road unit becomes a rail car, and vice-versa.

While handling technology has influenced the development of intermodalism, another important factor has been changes in public policy. **Deregulation** in the United States in the early 1980s liberated firms from government control, a policy that was tend adopted in many transport markets across the world. Companies were no longer prohibited from owning across modes, which developed a strong impetus towards intermodal cooperation. Shipping lines began to offer **integrated rail and road services** to customers. The advantages of each mode could be exploited in a seamless system, which created multiplying effects. Customers could purchase the service to ship their products from door to door, without being concerned about modal barriers.

The most important feature of intermodalism is providing a service with **one ticket** (for passengers) or **one bill of lading** (for freight). With one bill of lading, clients can obtain one through rate, despite the transfer of goods from one mode to another. This has necessitated a revolution in organization and information control. At the heart of modern intermodalism are data handling, processing, and distribution systems that are essential to ensure the safe, reliable, and cost-effective control of freight and passenger movements being transported by several modes. **Electronic Data Interchange** (EDI) was initially developed to assist companies and government agencies (customs documentation) in coping with an increasingly complex global transport system. This technology has now evolved, and with **digitalization**, crucial information can be shared across modes.

Intermodal transport is transforming the medium and long-haul freight flows across the globe. Large **integrated transport carriers** provide door to door services, such as the high degree of integration between maritime and rail transport in North America. In Europe, intermodal rail services are becoming well-established between the major ports, such as Rotterdam and southern Germany, and between Hamburg and Eastern Europe. Rail shuttles are also making their appearance in China. While intermodal rail transport has been relatively slow to develop in Europe, there are extensive interconnections between barge services and ocean shipping, particularly on the Rhine. Barge shipping offers a **low-cost solution to inland distribution** where navigable waterways penetrate to interior markets. The limits of intermodality are imposed by factors of space, time, form, the network pattern, the number of nodes and linkages, and the type and characteristics of the vehicles and terminals.

Section 2.3 Containerization

The box (container) is what makes the world go round.

The driver of intermodal transportation has undoubtedly been the **container**, which permits easy handling between modal systems. While intermodalism could take place without the container, it would be very inefficient and costly. The begin with, a distinction is necessary between containerization and the container.

***Container**. A large standard size metal box into which cargo is packed for shipment aboard specially configured transport modes (ISO 668). It is designed to be moved with common handling equipment enabling high-speed intermodal transfers in economically large units between ships, railcars, truck chassis, and barges using a minimum of labor. The container, therefore, serves as the load unit rather than the cargo contained therein. **The reference size is the 20-foot box of 20 feet long, 8'6" feet high and 8 feet wide, or 1 Twenty-foot Equivalent Unit (TEU)** (this is my standard size for design purposes – this author). Since most containers are now forty feet long, the term **Forty-foot Equivalent Unit** (FEU) is also used, but less commonly. "Hi cube" containers are also common, and they are one foot higher (9'6") than the standard.*

***Containerization**. Refers to the increasing and generalized use of the container as a load unit for freight transportation. It involves processes where the intermodal container either substitutes cargo from other conveyances, is adopted as a mode supporting freight distribution, or can diffuse spatially as a growing number of transport systems are able to handle containers.*

Containerization conveys a variety of benefits to the mobility of freight, namely lower transportation costs, lower inventory costs and a higher service level, including reliability.

Panamax Containership at the Port of Le Havre (being unloaded by a Portainer with standard sized containers – this author).

40-Foot Containers Doublestacked on a Rail Car

The development of intermodal transportation and containerization are mutually inclusive, self-strengthening, and rely on a set of driving forces linked with technology, infrastructures, and management. One of the initial issues concerned the different sizes and dimensions of containers used by shipping lines, a source of much confusion in compiling container shipping statistics. A lift could involve

different volumes since different box sizes were involved. As a result, the term TEU (Twenty-foot Equivalent Unit) was first used by Richard F. Gibney in 1969, who worked for the Shipbuilding & Shipping Record, as a comparative measure. Since then, the TEU remains the standard measure for containerized traffic.

The usage of containers shows the complementarity between freight transportation modes by offering a higher fluidity to movements and standardization of loads. The container has substantially contributed to the adoption and diffusion of intermodal transportation, which has led to profound mutations in the transport sector. By reducing handling time, labor costs, and packing costs, container transportation allows considerable improvement in the efficiency of transportation. Thus, the relevance of containers is not what they are – simple boxes – but what they enable; intermodalism. Globalization could not have taken its current form without containerization.

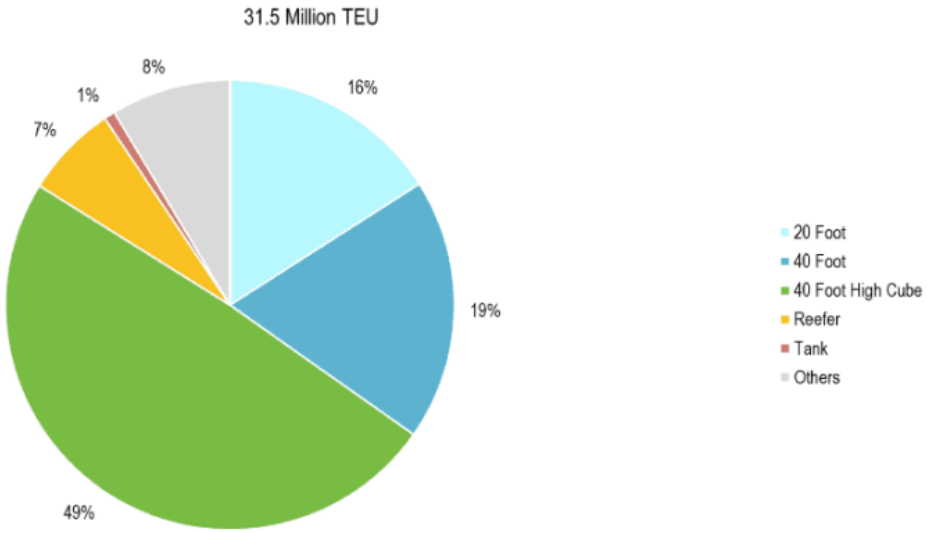
Containers are either made of steel (the most common for maritime containers) or aluminum (particularly for domestic containers), and their structure confers flexibility and hardiness. Another factor behind the diffusion of the container is that an agreement about its base dimensions and latching system was reached through the International Standards Organization (ISO 668) within ten years of its introduction. From this standard, a wide variety of container sizes and specifications have been put in use. The length unit for containers remains the imperial foot even if most countries use the metric system, a legacy that the standard was initially introduced in the United States. However, the most prevalent container size is the 40-foot box, which in its 2,400 cubic feet, which carry on average 22 tons of cargo. However, transporting cargo in a 20-foot container is usually 20% cheaper than transporting cargo in a 40-foot container. Irrespective of the size, a 20-foot container requires the same number of intermodal movements even if it takes about half the space during transport and at terminals.

Containers can be designed to carry a wide range of goods, which involves a level of specialization around five main types:

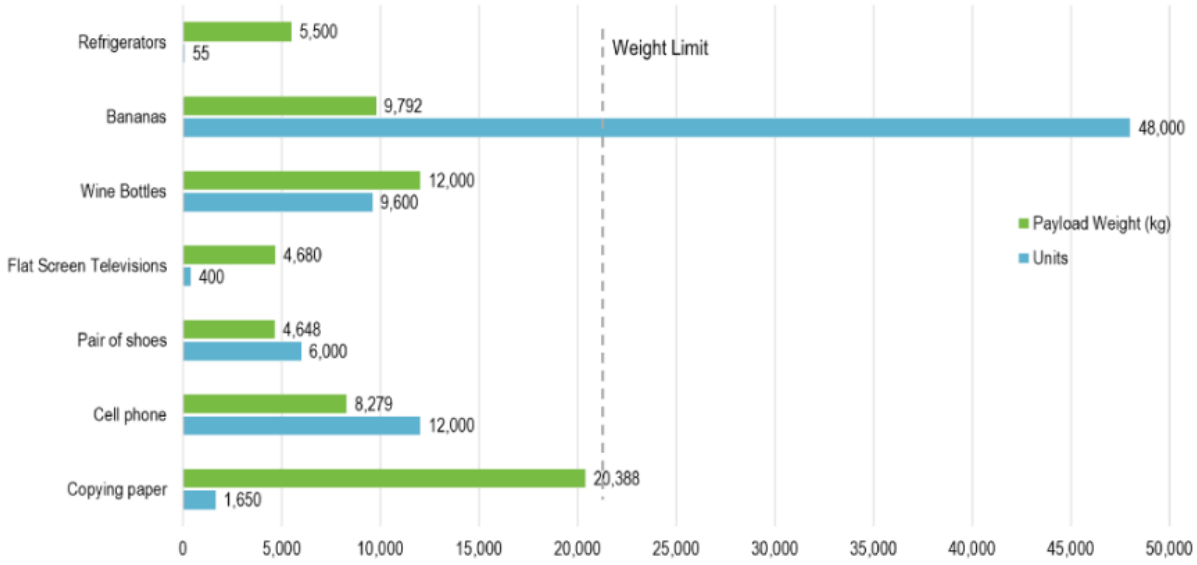
- **Standard container**. Containers that are designed to carry a wide variety of general cargo. They are often labeled as dry containers because they carry dry goods either in breakbulk (most common) or bulk (less common). Cargo

is loaded and unloaded through a double door, which marks the "backside" of the container.

- **Tank container**. Containers designed to carry liquids (chemicals or foodstuff). It is composed of a tank surrounded by a structure making it the same size as a standard 20-foot container, including its four latching points.
- **Open top container**. A container with an open roof designed to carry cargo is too large to be loaded through standard container doors, such as machinery. The container is loaded from the top with a tarpaulin used to cover its contents.
- **Flat container**. A container having an open roof and sides designed to carry heavy and oversized cargo. The cargo transported is left exposed to outdoor conditions.
- **Refrigerated container**. Also known as a **reefer**, it is a container designed to carry temperature-controlled cargo, often around or below freezing point. It is insulated and equipped with a refrigeration plant maintaining the temperature constant.



Composition of the Global Fleet of Containers, 2012



Number of Units and Weight of Standard Consumption Goods that Can be Carried by a 20 Foot Container.

A significant share of international containers is either owned by shipping lines that tend to use them as a tool to help fill up their ships or by leasing companies using containerized assets for revenue generation. In the United States, a large number of domestic containers of 53 feet are also used (of course we had to be different but not in the coming future – this author). Doublestacking of containers on railways (COFC: Containers On Flat Cars) has doubled the capacity of trains to haul freight with minimal cost increases, thereby improving the competitive position of the railways with regards to trucking for long-haul shipments.

While it is true that the maritime container has become the workhorse of international trade, other types of containers are found in certain modes, most notably in the **airline industry**. High labor costs and the slowness of loading planes that require a very rapid turnaround made the industry very receptive to the concept of a loading unit of standard dimensions designed to fit the specific shape of the bellyhold. The maritime container was too heavy and did not fit the rounded configuration of a plane's fuselage, and thus a box specific to the needs of the airlines was required. The major breakthrough came with the introduction of wide-bodied aircraft in the late 1970s. Lightweight aluminum boxes, called unit load devices (which this author outlines in his nextgen air freighter design later in this paper) could be filled with passenger's baggage or parcels and freight, and loaded into the holds of the planes using tracking that requires little human assistance.

Containerization represents a r**evolution in the freight transport industry**, facilitating economies of scale and improved handling speed and throughput. Containerized traffic surged since the 1990s. This underlines the adoption of the container as a dominant means to ship products on international and national markets, particularly for non-bulk commodities where the container accounts for more than 90% of all movements. Containerization leans on growth factors mainly related to globalization, substitution from breakbulk, and, more recently, the setting of intermediate transshipment hubs. Although containerization initially superimposed itself over existing transportation systems, it created its **own unique system of exclusive modes and terminals**. Thus, the container became a standard unit around which a new transportation system was built.

Globalization and containerization as closely interrelated. According to UNCTAD, between 1970 and 1990, trade facilitation measures accounted for 45% of global trade growth while membership to global trade organizations such as GATT/WTO accounted for another 285%. The container accounted for an additional 790%, exceeding all the other trade growth factors put together. The diffusion and adaptation of transport modes to containerization is an ongoing process that will eventually reach a level of saturation. Containers have thus become the most important component for rail and maritime intermodal transportation. The challenge remains about the choice of modes in an intermodal transport chain as well as minimizing the costs and delays related to moving containers between modes. As the use of intermodal transportation increased and became more complex (e.g., international trade), transactional costs and inefficiencies became increasingly apparent. Innovations involve using blockchain technology (I advocate this in nearly every paper that I do – this author) as distributed electronic ledgers, to support the complex array of transactions and information flows related to intermodal transportation.

Section 2.4 Advantages and Challenges of Containerization

Among the numerous advantages related to the success of containers in international and hinterland transport, it is possible to note the following.

a. Standard transport product

A container can be manipulated anywhere in the world as its dimensions are an **ISO standard** (except in the USA at present – this author). Indeed, transfer infrastructures allow all elements (vehicles) of a transport chain to handle it with relative ease. Standardization is a prevalent benefit of containerization as it conveys a ubiquity to access the distribution system and reduces the risks of capital investment in modes and terminals.

The rapid diffusion of containerization was facilitated because its initiator, Malcolm McLean, purposely did not patent his invention. Consequently, all segments of the industry, competitors alike, had access to the standard. It necessitated the construction of specialized ships, lifting equipment, and terminal facilities. Still, in several instances, existing transport modes could be converted to container transportation, at least while a more effective transition to containerization took place. In time, the container became the standard transport unit of global trade.

b. Flexibility of usage

A container can transport **a wide variety of goods** ranging from raw materials (coal, wheat), manufactured goods, and cars to frozen products. There are specialized containers for transporting liquids (oil and chemical products) and perishable food items in refrigerated containers (which now account for 70% of all refrigerated cargo transported). About 2.9 million TEUs of reefers were being used by 2018. Discarded containers are often used as storage, housing, office, and retail structures.

As an indivisible unit, the container carries a unique identification number and a size type code, enabling transport management not in terms of loads, but in terms of **units**. This identification number is also used to ensure that it is carried by an authorized agent of the cargo owner and is verified at terminal gates, increasingly in an automated fashion. Computerized management enables to reduce waiting times considerably and to know the location of containers (or batches of containers) at any time. It assigns containers according to the priority, the destination, and the available transport capacities. Transport companies book slots in maritime or railway convoys that they use to distribute containers under their responsibility. As such, the container has become a production, transport, and distribution unit.

20-Foot Tank Containers

c. Economies of scale

Relative to bulk, container transportation reduces transport costs considerably, about 20 times less. While before containerization, maritime transport costs could account between 5 and 10% of the retail price, this share has been reduced to about 1.5%, depending on the goods being transported. The main factors behind cost reductions reside in the speed and flexibility incurred by containerization. Like other transportation modes, container shipping is benefiting from economies of scale by using larger containerships.

The 6,000 TEU landmark was surpassed in 1996 with the Regina Maersk, and in 2006 the Emma Maersk surpassed the 12,000 TEU landmark. By 2013, ships of more than 18,000 TEU became available. A 5,000 TEU containership has operating costs per container 50% lower than a 2,500 TEU vessel. Moving from 4,000 TEU to 12,000 TEU reduces operating costs per container by a factor of 20%, which is very significant, considering the additional volume involved. System-wide, the outcome has been costs reductions of about 35% using containerization.

d. Operational velocity

Transshipment operations are minimal and rapid, which increases the utilization level of the modal assets and port productivity. A modern container ship has a monthly capacity of 3 to 6 times more than a conventional cargo ship. This is notably attributable to gains in **transshipment time** as a crane can handle roughly 30 movements (loading or unloading) per hour. Port turnaround times have thus been reduced from an average of 3 weeks in the 1960s to **less than 24 hours** since it is uncommon for a ship to be fully loaded or unloaded along regular container shipping routes.

It takes on average between 10 and 20 hours to unload 1,000 TEUs compared to between 70 and 100 hours for a similar quantity of bulk freight. With larger containerships, more cranes can be allocated to transshipment; 3 to 4 cranes can service a 5,000 TEU containership, while ships of 10,000 TEU can be serviced by 5 to 6 cranes. The latest generation of 18,000 to 20,000 TEU containerships requires 6 to 9 cranes to be effectively serviced. This implies that larger ship sizes do not have many differences in loading or unloading time, but this requires more yard equipment. A regular freighter can spend between half and two-thirds of its useful life in ports. With less time in ports, containerships can spend more time at sea. Based on Automatic Identification Service (AIS) data, a containership spends around 40% of its time stationary. Since a ship generates revenue while at sea, containerships are more profitable. Further, containerships are, on average, 35% faster than regular freighter ships (19 knots versus 14 knots). It is estimated that containerization has reduced travel time for freight by a **factor of 80%**.

e. Warehousing and security

The **container is its own warehouse** and limits damage risks for the goods it carries because it is resistant to shocks and weather conditions. The packaging of goods it contains is, therefore, simpler, less expensive, and can occupy less volume. This reduces insurance costs since cargo is less prone to be damaged during transport. Besides, containers fit together, permitting stacking on ships, trains (doublestacking), and on the ground. The stacking height of containers is constrained by a permissible weight of 192 tons. With 30 tons per container, this would correspond to a pile of 6 containers in height. However, due to the operational complexity of high piles, staking usually superimposes three to four loaded and six empty containers on the ground.

The contents of the container are anonymous to outsiders as it can only be opened at the origin, at customs, and at the destination. Thefts, especially those of valuable commodities, are considerably reduced, resulting in lower insurance premiums. Theft was a serious issue at ports before containerization as longshoremen had direct access to the cargo, they were handling.

Even if there are numerous advantages in the usage of containers, some challenges are also evident.

f. Site constraints

Containerization implies a large **consumption of terminal space**. To fully load or unload a containership of 5,000 TEU, a minimum of 12 hectares of stacking space is required. Conventional port areas are often not adequate for the location of container transshipment infrastructures, particularly because of draft issues as well as required space for terminal operations. Many container vessels require a draft of at least 14 meters (45 feet), and the later generation of larger ships require at least 15 meters (50 feet). A similar challenge applies to container rail terminals, many being relocated at the periphery of metropolitan areas. Consequently, major container handling facilities have new location criteria where suitable sites are only found at the periphery.

g. Infrastructure costs and stacking

Containerization is a **capital-intensive endeavor**. Container handling infrastructures, such as gantry cranes, yard equipment, road, and rail access, represent important investments for port authorities and terminal operators. For instance, the costs of a modern container crane (portainer) are in the range of 4 to 10 million USD depending on the size. Several developing economies, as well as smaller ports, face the challenge of finding capital for these infrastructure investments.

The arrangement of containers, both at terminals and on modes (containerships and double-stack trains) is a complex problem. When loading, it becomes imperative to make sure that containers that must be taken out first are not below a pile. Further, containerships must be loaded in a way to avoid any restacking, along with its numerous port calls where containers are loaded and unloaded.

h. Thefts and losses

While many theft issues have been addressed because of the freight anonymity a container confers, it remains an issue for movements outside terminals where the contents of the container can be assessed based upon its final destination. The World Shipping Council estimated that, on average, 546 containers are lost at sea each year under normal operating conditions, a figure that climbs to 1679 containers if events such as ship collisions and sinking are included. Rough weather is the major cause of container losses, but improper container stacking also plays a role (distribution of heavy containers). Yet, the loss rate remains very low since 5 to 6 million containers are being transported at any given time.

i. Empty travel

Maritime shippers need containers to maintain their operations along with the port networks they service. The same number of containers brought into a market must eventually be relocated, regardless of whether they are full or empty. On average, containers will spend about 56% of their 10 to 15 years lifespan **idle or being repositioned empty**, which is not generating any income but conveys a cost that is part of the shipping rates. Either full or empty, a container takes the same amount of space on the ship or in a storage yard and takes the same amount of time to be transshipped. Due to a divergence between production and consumption, it is uncommon to see equilibrium in the distribution of containers.

About 2.5 million TEUs of empty containers are stored in yards and depots worldwide, underlining the issue of the movement and accumulation of empty containers. They represent about 20% of the global container port throughput and the volume carried by maritime shipping lines. Most container trade is imbalanced, and thus containers “accumulate” in some places and must be shipped back to locations where there are deficits (mostly locations having a strong export function). This is particularly the case for American container shipping. As a result, shipping lines waste substantial amounts of time and money in repositioning empty containers.

j. Illicit trade

By its confidential character, the container is a common instrument used in the illicit trade of counterfeit goods, drugs, and weapons. At the global level, only 2 to

5% of all containers handled at ports are manually inspected by customs, leaving opportunities for **illicit cargoes**. This share can go as low as 1% for several large European ports. Manually inspecting a container requires physical resources such as inspection areas as well as labor resources. Thus, assessing if a container should be physically inspected is the outcome of careful considerations related to their origin, the customs declaration, the carrier, and the cargo owner. Concerns have also been raised about containers being used for terrorism. These fears have given rise to an increasing number of regulations aimed at counteracting the illegal use of containers. In 2003, following US inspection requirements, the International Maritime Organization (IMO) introduced regulations regarding the security of port sites and the vetting of workers in the shipping industry. The US itself established a 24-hour rule, requiring all shipments destined for the US to receive clearance from US authorities 24 hours before the departure of the vessel. In 2008, the US Congress passed a regulation requiring all US-bound containers to be electronically scanned at the foreign port of loading, before departure. These measures incur additional costs and delays that many in the industry oppose.

Yet, the advantages of containerization have far outweighed its drawbacks, transforming the global freight transport system and, along with it, the global economy."

SECTION 3 – WHAT PROBLEMS AND SOLUTIONS EXIST FOR THE ADVENT OF TRANSMODAL TRANSPORTATION.

As always, better said by others.

A citation from: United Nations, Geneva 2020 – Review of Maritime Transport, https://unctad.org/system/files/official-document/rmt2020_en.pdf

“The setting of global freight transportation networks is mainly supported by maritime transport which has become highly efficient in terms of costs, capacity, and reliability. However, the rapid growth of maritime containerized shipping has placed intense pressures on inland freight transportation systems, particularly rail. In such a context there is a growing recognition that rail freight is critical and there are expectations that rail transport systems will accommodate growing inland freight volumes that road transport systems cannot handle effectively. The question remains about the extent to which these expectations are going to be met in terms of capacity but also in terms of level of service. A particular issue pertains to the requirements of contemporary freight distribution, which is increasingly flexible and time based (Bontekoning and Priemus, 2004; Deardorff et al., 2005).

Even if rail was conventionally a mode that could not be effectively reconciled with those requirements, this perspective has changed with globalization, containerization, and privatization (deregulation).

Thus, rail transport is facing a resurgence triggered by a simple matter of growing demand as well as by a new set of conditions affecting the industry, making it increasingly flexible and time responsive, or at least sensitive to those issues.

Issues and constraints concerning the intermodal function of freight distribution are well known (e.g., TRB, 1998). In the context of North America, it is argued that the issue of ‘‘transmodal transportation’’ (movement within the segments of a mode) needs to be addressed further as connectivity between long distance rail segments is becoming increasingly problematic. This represents one of the key issues to improve the efficiency of rail freight distribution on such a large system of freight circulation. Additionally, forecasting future freight demand is increasingly difficult to assess because of the uncertainties and complexities linked with globally oriented supply chains, surging energy prices, business cycles, volatility brought by fiat currency systems, the strategies of global freight

forwarders (notably third-party logistics providers and port operators), congestion and security issues.

North American context

In North America the resurgence of rail has particularly resulted in a growth of ton-miles, favoring the intrinsic advantages of rail as a long-distance freight carrier (Fig. 1). This observation is also substantiated by the growth of international trade and of trade imbalances, which accelerated in the 1990s. The synchronism between rail and coastal transportation was broken right after the Ocean Shipping act of 1984, permitting maritime companies to rationalize and consolidate their operations by authorizing intermodal services between ocean and inland carriers (Talley, 2000). This negatively impacted coastal operations (coastal services could be bypassed more effectively) and part of the market, at least the growth potential, was assumed by rail. While port transshipments increased, coastal operations declined as well as the number of barges. This phase of devolution appears to be completed and a higher level of integration between coastal and rail transport systems can be expected, particularly with short sea shipping services.

The substantial growth in rail traffic is not without challenges. On par with major port gateways, inland rail transportation is getting congested, even with the significant capacity benefits achieved by the double stacking and double tracking of several corridors. In fact, additional capacity has almost disappeared from the American rail system. This has the potential to significantly curtail the future growth of the American economy since additional freight transportation demands, on roads as well as on rail, are not going to be fully met (Boardman, 2006). Rail congestion is particularly reflected at major hubs, such as Chicago, that appear to have reached substantial capacity constraints in handling growing quantities of containerized rail freight shipments. Considering the structure of long-distance trade, road transportation cannot effectively accommodate additional growth for a variety of reasons, particularly in terms of costs and capacity. From a situation of modal competition between road and rail, there is an emerging complementarity, particularly for containerized shipments. While it costs about $1,500 to move a 40-foot container from the West Coast to Chicago, the same shipment costs $3,000 by truck (Prince, 2006). Average domestic haul lengths have increased by 24.0% and 18.7%, respectively between 1990 and 2003, placing them at 775 km for road and at 1380 km for rail. The growth in the haul length for trucking is not likely to increase significantly due to additional energy

and labor costs and empty travels such distances create. About 80% of interurban freight traffic in the United States is carried over distances of less than 640 km. The remaining 20% accounts for 130 million loads per year and this figure excludes international trade shipments that are commonly carried nationally over long distances. This segment of the market offers significant opportunities for medium distance rail as long as the transport time segment can be mitigated (which rapid load/unload and hydrocarbon free locomotives could transform- this author).

The net advantage of trucking for medium distances is not necessarily related to its speed, but to the intermodal costs and delays at rail terminals, which makes shippers wary of using rail. Any improvements in the efficiency of intermodal rail are likely to change its relation to trucking in a significant manner. It is under such circumstances that the transmodal dimension is of particular relevance.

Transmodal transportation and the Thruport concept.

With improvements in the capacity, efficiency and reliability of freight distribution, integrated transport systems have become a leading paradigm. The conventional fragmented and sub-optimal freight transport systems have substantially been changed by intermodal transportation and the combination of several modes servicing commodity chains, many of them globally oriented. The advantages of each mode and terminals, used in conjunction, create multiplying effects.

A process of coordination of freight transport is taking place, from which substantial financial and operational benefits are derived. Several factors can be pondered in this development:

1) Technology: Containerization is without any doubt the most significant technological factor behind a more efficient coordination of transport modes. Innovations from which additional capacity and efficiency are derived include modes, such as post-panamax containerships.

“A Thruport is designed to accommodate fragmented markets, supply chains and ownership, notably when this fragmentation takes place at a large scale (USA – this author).”

2) Market fragmentation: The first rationale behind transmodal transportation is market fragmentation, particularly for the retailing stage. Since retailing

> leans heavily on global production and national distribution, the system depends on gateways forwarding freight along long distance rail corridors. The gateways (ports for the most part) are limited in number and the markets are excessively diverse. Thus, this represents a distributional setting in which the Thruport acts as a hub where the containers are shuffled to their respective unit trains bound to specific markets. The market however needs to be large enough to justify this level of shipments. The efficiency of gateways to accommodate intermodal (transmodal – this author) traffic would thus be linked with the efficiency of the Thruport.
>
> In some cases, the efficiency of ports and inland freight transportation can promote imports more than regional manufacturing, especially if the latter relies on a different and less efficient distribution channel. In a situation of labor costs differences, this may create a multiplying effect making imports even more advantageous since they would offer cost as well as time benefits. A Thruport can improve the efficiency of long-distance distribution by acting as a location where containerized freight can be fragmented and assembled in batches (unit trains) bound for specific regional markets.

"In the first case, the volume is sufficient enough to simply be a matter of fragmentation. However, it is more likely that a Thruport would be the assembly and redistribution point of freight coming from several gateways."

3) Supply chain fragmentation: Contemporary supply chains involve a complex sequence of tasks. These tasks are the outcome of a specialization of economic activities and the exploitation of comparative advantages at the regional and often at the global scale. This fragmentation has placed intense pressures on freight distribution systems, including rail, to accommodate the growth in traffic in terms of volume and tons-km. The different stages of a supply chain, ranging from parts and raw materials, to manufacturing and distribution, could benefit from a closer time-wise integration permitted by a Thruport. The benefits would notably involve lower distribution costs, lower inventory levels and a higher level of reliability, notably with timely distributions."

SECTION 4 – WHAT NEXTGEN TRANSMODAL FREIGHT TRANSPORTS LOOKS LIKE

Nextgen transmodal freight transports or "prime movers" will include [1] non – hydrocarbon maritime propulsion systems, [2] high speed rail locomotives with non – hydrocarbon propulsion systems, [3] containers on barge with fully renewable energy powered propulsion systems, [4] semi-trucks with fully electric propulsion systems (by others) closely coupled with carbon fixed nextgen concrete roadbeds and [5] non-hydrocarbon / electric drive freight aircraft capable of STOL / VTOL operation.

This section represents a conceptual body of work conceived by this author largely within calendar years 2019 / 2020. It is meant to represent what the reality of such propulsion systems will look like, function like and cost (within broad bounds) in calendar year 2030 – 2040 and beyond. No new science is needed, just careful engineering meant to capture the needs of the time.

Section 4.1: Non-hydrocarbon marine propulsion systems

Packaging power generation, its associated power management and distribution is a surprisingly difficult to achieve goal when working to meet Marine (maritime), MilSpec or SmartGrid needs. It doesn't take much imagination to understand why this is a truism.

A sizeable resource and research publication library has been assembled and should be used accordingly if interest proves favorable.

This author has identified several applications that as mentioned above can readily be developed and deployed broadly. Marine powergen would be highly scaleable with modular units likely being developed in the 50 – 150 MW-h (or much more) range with high amperage DC available on a 24/7 basis for an integrated unit cost of ~ $400,000 – several million USD. Said units would be capable of sustained operation in all climactic conditions with industry standard uptimes and efficiency or much better. Commercial development monies can likely be provided by USDOD / DARPA and USDOE grants. Once decently proven up the private sector could conduct the rollout for a very substantial profit.

Reiterating, the target application for this summary report is power generation (powergen) for onboard marine needs that replaces the need for hydrocarbon or nuclear-powered systems for propulsion and other shipboard uses. It does however require a small volume of startup only dedicated compressed oxygen and hydrogen supplied by conventional means which are widely available at ports worldwide.

Replacing nuclear, diesel or other hydrocarbon fueled powergen system allows sustained operation for this application with many obvious implications for both military and civilian needs in the event of a sustained logistical supply chain disruption of any kind. The sun doesn't have to shine, the wind doesn't have to blow, and nuclear waste handling and disposal doesn't matter.

Concept

This power generation system will create its own fuels from atmospheric gases (hydrogen and oxygen) and then via a proven hydrogen / oxygen expanding gas

combustion turbine drive to a coupled power generator that will charge a dedicated bank of sized for the application batteries (think TeslaWall). Said batteries will supply the DC local onboard grid on a demand basis. Offgrid but still local demand would be dealt with using portable ultracapacitors mounted on this system for charging/recharging. The system should be designed for 24/7/365-day operation with at least 12 months before first periodic port maintenance.

The forms of "emission" from this power generation system would be excess to need heat, disinfected drinking water, NOx, and CO2. The NOx and CO2 can be readily disposed of by dissolving them in excess to need shipboard water and then be wake dispersed with no environmental hazard or tracking issues. In a sense this represents a very stealthy powergen system.

Avoiding power generation output issues that can vary substantially with both ambient temperature and humidity requires the use of a high alloy intercooled two or three or more compressor stage set of serially piped turbines with supplemental water injection as needed. I do also advocate that these turbine sets be installed in parallel multiples to provide scaleable power and necessary backup.

An illustration of the basic process also with some notes by others is below. It's citation:

Sanz, Wolfgang, Martin Braun, Herbert Jericha, and Max F. Platzer. "Adapting the Zero-Emission Graz Cycle for Hydrogen Combustion and Investigation of Its Part Load Behaviour." In *Turbo Expo: Power for Land, Sea, and Air*, vol. 49743, p. V003T06A020. American Society of Mechanical Engineers, 2016.

"PROCESS DESCRIPTION OF A GRAZ CYCLE PLANT FOR HYDROGEN COMBUSTION

Figure 1 shows the principal flow scheme of the Graz Cycle plant for hydrogen combustion, and Fig. 2 the associated temperature-entropy (T-s) diagram generated by the software IPSEpro. The plant is based on a proposal by Jericha [9] and consists basically of a high-temperature Brayton cycle and a low-temperature Rankine cycle – a combined cycle. The Brayton part consists of the combustion chamber (CC), the high-temperature turbine (HTT) and the compressors (C1/C2). The Rankine steam loop consists of the heat recovery steam generator (HRSG), high-pressure steam turbine (HPT), low pressure steam turbine (LPT), condenser,

condensate pump, deaerator and finally the feed pump supplying high pressure water to the HRSG.

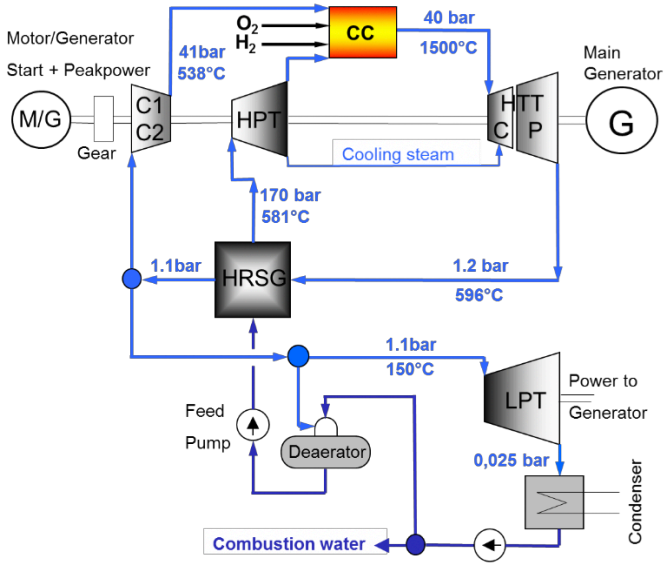


Fig. 1: Principal flow scheme of the Graz Cycle for hydrogen/oxygen combustion”

Maintaining consistent and predictable power generation is key for this process to work. The key is aggressive heat management as shown above.

Put another way: "Generally, unlike the heat rate, the net power output from a gas turbine decreases with an increase of the ambient air temperature. This is due to reduced net power output, which is directly proportional to the air mass flow rate; net power produced decreases when the ambient air temperature increases. Practically, a 25% loss of the rated power capacity of the gas turbine at ISO conditions as the ambient temperature reaches 40 °C is reported."

Given that this process issue can be easily overcome by design then this concept then becomes compelling given the likely deployment locales. These locales will be highly variable and its effective mitigation of power loss by design becomes crucial.

In all instances all sub-systems are well proven. No new technology is required.

This author knows that a consistent and appreciable volume of relatively pure H2 / O2 are needed. My concept description for this is just below:

A blower driven raw atmosphere intake contacts a set of three sequentially mounted molecular sieves that would remove [1]water vapor, [2]methane/carbon dioxide and [3]nitrogen from the intake atmosphere volume. The "concentrated" downstream "gas" would be 90%+ oxygen would be compressed in a storage tank and directly used in the combustion process.

Then the molecular sieve separated [2]methane/carbon dioxide would be purged or cleaned from its' molecular sieve using a small volume of the compressed oxygen on a timed basis. The purged volume of methane/carbon dioxide/oxygen would be captured, compressed, and then processed at low pressure (<2bar) and ambient temperature through a photoelectrochemically powered tubular or sheet assembled, optically clear, covered methane "reformer" or "cracker" to make a compressed hydrogen and oxygen product with a small volume of residual of carbon dioxide as a contaminant. The [1]water vapor molecular sieve would be similarly purged with the excess [3]nitrogen gas on a timed basis with the balance of the nitrogen vented to atmosphere.

Commercially this atmospheric gas separation can be described as a VSA, PSA or VPSA any of which could work. Commercial vendors for the appropriate molecular sieve materials and the gas separation systems exist and should be thoroughly explored and then used as appropriate.

Maintenance needs are expected to be very low and should require nearly or no skilled labor to operate.

Commercially this system will be attractive from both a cost to construct and use (deploy) perspective especially when compared to either conventional or other unconventional energy systems. This option would keep the lights on and electronics working and properly disinfected drinking water flowing.

Alternatively, if the hydrogen supply is too small, compressed or cryogenic / liquid supplied methane / natural gas could be used although this would assume that some form of on demand logistic supply was available.

This author has previously specified use of magnetic bearings and transmissions for all applicable systems for similar, although smaller, applications. These are widely available and nicely sized for these applications which would eliminate most of the problems found with rotating machinery and their maintenance.

Again, this author does advocate close integration with other renewable energy generation and storage systems to increase supply optionality in the event of a national and / or regional grid outage of significant duration.

Marine Powergen Summary Notes

- All components must be capable of in place maintenance and replacement.
- All components or their associated critical duty items.
- All external power generated shall first charge on board batteries.
- All external power supplied shall be DC or AC for HVAC needs.
- All mission critical replacement components must be local stocked.
- All onboard control systems to be hardened 24VDC.
- All onboard power systems to be DC (Insight).
- Batteries shall be capable of distribution and load balancing.
- CO2 sequestration for this application is contraindicated.
- Deployment of said system into full operation shall not be more than ten minutes from a dead start with charged batteries (Insight).
- Atmospheric emissions shall be low temperature water vapor and trace amounts of NOx well below background levels (Insight).
- Water emission of CO2 shall be dissolved, and wake dispersed well below background levels (Insight)
- H2/O2 expanding gas turbine power generation must be capable of supplying all on board power needs plus at least 25% of peak demand into the on-board storage battery / ultracapacitor banks.
- H2/O2 heat recovery shall be recycled for pre-heat and methane reformer needs then vented to atmosphere.
- H2/O2 vent shall have provision for drinking water supply from a dedicated supply tank.
- H2/O2 water supply shall have on board NaOCl generation from "table" salt and dosing hardware for disinfection of the supply tank (Insight).
- Shipboard AC /HVAC qualify for integration with a 6 - 10% inversion penalty.
- Methane cracker must be capable of providing at least a 50%+ hydrogen product @ 2 bar pressure (Insight).
- Power systems must be capable of 99%+ uptime operation.
- Power systems must be capable of sustained stand down or storage - on the order of years with no penalty (Insight).
- Power systems must be fully capable of offline no external access (Insight).

- Power systems (preferably 3 or more - 50MW or more units) shall be capable of 24/7/90 day operation before significant onboard maintenance.
- Molecular sieve materials must be fines removal pre-sieved then triple bagged with an appropriated desiccant for long-term on-board storage.
- PSA / VPSA or VSA must provide a 90%+ gaseous O2 product @ 2 bar pressure.
- PSA / VPSA or VSA must provide a 90%+ methane / CO2 blended product @ 2 bar pressure.
- PSA / VPSA or VSA must provide a 90%+ nitrogen product.
- Power systems must be easily integrated and coupled / decoupled with existing onboard drive systems.
- Power system turbines should be two or more output shaft capable to provide flexibility in drive and onboard power system integration and / or repair while at sea.
- Said power systems batteries must be capable of providing at least +50% of peak demand for a 4-hour span (Insight).
- Power systems must be of unitized construction and capable of 4-hour changeout in port, not drydock (Insight).
- Said systems must provide enough power for mission critical sub systems.
- Startup external power supply shall be capable of 10-minute deployment support.
- Ultracapacitor components shall be capable of multiple recharges from the battery outputs.
- Ultracapacitor components shall be provided suitable for startup and operational needs.
- Ultracapacitor output shall be on board DC or AC voltage / amperage selectable (Insight).

Conclusion

This unit, its various technologies and its intent are meant to solve the pressing need for a critical application - high speed low emission at scale marine surface drives. It is meant to be easily fit and repeatedly deployed. It is meant to be “hack proof”. It can not only provide 150 mW-H ++ of power (or much more) but also a significant volume and consistent source of potable drinking water and shipboard heat. It only needs our atmosphere and some humidity to work which on shipboard should not be difficult to find.

Section 4.2: High speed rail locomotives with non – hydrocarbon propulsion systems

The early adoption and then more widespread use of energy sources that both save money and increase profitability is not a new idea for entrepreneurs, scientists and governments and is a goal they aspire to achieve. Everyone wants to innovate or create the latest big thing that pushes society forward toward a yet brighter future hopefully for a large profit.

I take that paradigm and push it yet another step forward. I espouse the adoption of stepchange technologies that can offer least cost operation for least risk without the need for hydrocarbon energy sources. This simple strategy certainly can apply in the rail transportation market just as it would apply to most markets. The technology changeover will offer a large profit opportunity for all stakeholders.

In this instance this strategy encompasses using a highly efficient non-hydrocarbon energy source and other closely integrated designs that already exist but above all else, those that are simple and cost efficient to deploy. It may not offer large profits for existing stakeholders, but most would endorse a least cost, least risk approach. Some may attempt a catch and kill approach regardless because change is a risk.

Answering “why” do it might be vital this point. Why – because we are in the grip of a global pandemic that has changed and largely disrupted our global economy in a staggeringly short period of time. Finding the way to recover our economy and its various supply chains while also conquering the pandemic becomes a first order priority. This global strategy could well use this author’s modest work as outlined herein to positive effect as a portion of that strategy.

A sizeable resource and research publication library has been assembled and should be used accordingly if interest proves favorable.

Railroads have proven to be cost and time efficient in the delivery of goods within a country’s borders and somewhat less so on a continental basis. Making this good (and people) delivery system yet more efficient and timely enough to

displace both truck and air delivery requires use of rolling stock of high speed and effiency for least cost. This can be done quickly.

The priority would be replacement of existing locomotive diesel powergen with a new powergen system capable of sustained high-speed transit with little downtime. This powergen would be highly scaleable with modular units likely being developed in the 5 –50 MW-h (or much more) range with high amperage AC available on a 24/7 basis for an integrated unit cost of ~ $300,000 – several million USD (less ancillary hardware that is pre-existing). Said units would be capable of sustained operation in all climactic and topography conditions with industry standard uptime and efficiency or much better. Commercial development monies can likely be provided by USDOE grants. Once decently proven up the private sector could conduct the rollout for a very substantial profit.

Reiterating, the target application for this summary report is least cost power generation (powergen) for onboard railroad locomotive needs that replaces the need for hydrocarbon combustion systems for propulsion and other uses. It does however occasionally require a small volume of startup only dedicated compressed oxygen and hydrogen supplied by conventional means which are or can be made easily and widely available at depots worldwide.

Replacing diesel or other hydrocarbon fueled powergen systems that allows for sustained operation for this application with a simple, easily maintained system has many obvious implications for both market profitability and civilian needs in the event of a sustained logistical supply chain disruption of any kind such as a pandemic or to help mitigate climate change. Affording to do the conversion can be easily done using the energy tax model this author has outlined many times in the recent past.

Concept

This power generation system will create its own fuels from atmospheric gases (hydrogen and oxygen) and then via a proven hydrogen / oxygen expanding gas combustion turbine drive to a coupled power generator that will charge a dedicated bank of sized for the application batteries (think TeslaWall). Said batteries will supply the AC local onboard grid on a demand basis. The system can be designed

for 24/7/365-day operation with at least 12 months before first periodic port maintenance.

The forms of “emission” from this power generation system would be excess to need heat as steam.

Avoiding power generation output issues that can vary substantially with both ambient temperature and humidity requires the use of a high alloy intercooled two or three or more compressor stage set of serially piped turbines with supplemental water injection as needed. I do also advocate that these turbine sets be installed in parallel multiples (probably two) to provide scaleable power and necessary backup working from an excess of caution.

An illustration of the basic process also with some notes by others is below. It’s citation:

Sanz, Wolfgang, Martin Braun, Herbert Jericha, and Max F. Platzer. "Adapting the Zero-Emission Graz Cycle for Hydrogen Combustion and Investigation of Its Part Load Behaviour." In *Turbo Expo: Power for Land, Sea, and Air*, vol. 49743, p. V003T06A020. American Society of Mechanical Engineers, 2016.

“PROCESS DESCRIPTION OF A GRAZ CYCLE PLANT FOR HYDROGEN COMBUSTION

Figure 1 shows the principal flow scheme of the Graz Cycle plant for hydrogen combustion, and Fig. 2 the associated temperature-entropy (T-s) diagram generated by the software IPSEpro. The plant is based on a proposal by Jericha [9] and consists basically of a high-temperature Brayton cycle and a low-temperature Rankine cycle – a combined cycle. The Brayton part consists of the combustion chamber (CC), the high-temperature turbine (HTT) and the compressors (C1/C2). The Rankine steam loop consists of the heat recovery steam generator (HRSG), high-pressure steam turbine (HPT), low pressure steam turbine (LPT), condenser, condensate pump, deaerator and finally the feed pump supplying high pressure water to the HRSG.

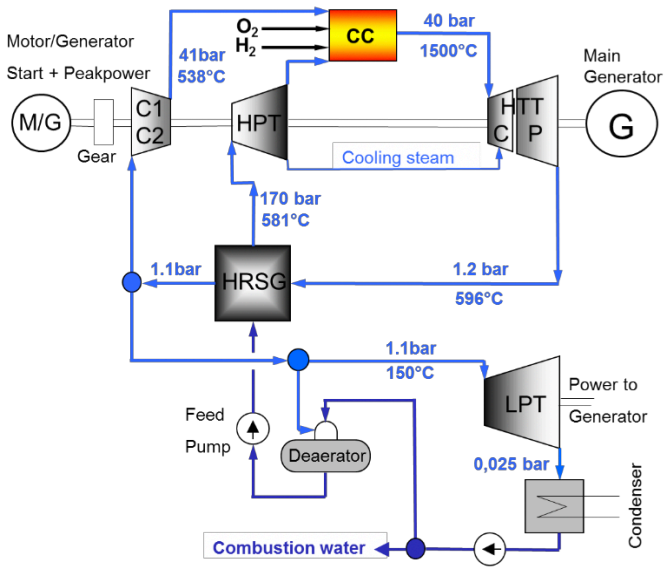


Fig. 1: Principal flow scheme of the Graz Cycle for hydrogen/oxygen combustion"

Maintaining consistent and predictable power generation is key for this process to work. The key is aggressive heat management as shown above.

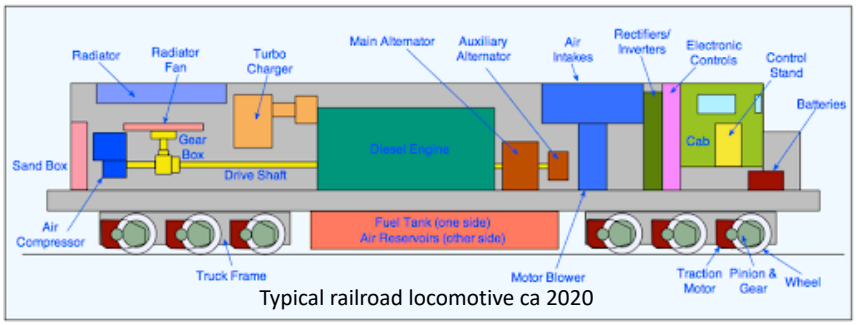
Put another way: "Generally, unlike the heat rate, the net power output from a gas turbine decreases with an increase of the ambient air temperature. This is due to reduced net power output, which is directly proportional to the air mass flow rate; net power produced decreases when the ambient air temperature increases. Practically, a 25% loss of the rated power capacity of the gas turbine at ISO conditions as the ambient temperature reaches 40 °C is reported."

Given that this process issue can be easily overcome by design then this concept then becomes compelling given the application at hand.

In all instances all sub-systems are well proven. No new technology is required.

This author knows that a consistent and appreciable volume of relatively pure H2 / O2 are needed. My concept description for this is just below as both a simple drawing and in text (see next page):

NEXTGEN LOCOMOTIVE DESIGN CONCEPT
GOAL MET: No external fuel needs.



Typical railroad locomotive ca 2020

Proposed design changes:
1) Delete turbo charger
2) Delete diesel engine
3) Replace diesel engine with MOF / PSA
4) Delete fuel tank / air reservoir
5) Replace fuel tank / air reservoir with O2/H2 storage tanks

A blower driven raw atmosphere intake contacts a set of three sequentially mounted molecular sieves that would remove [1]water vapor, [2]methane/carbon dioxide and [3]nitrogen from the intake atmosphere volume. The “concentrated” downstream “gas” would be 90%+ oxygen would be compressed in a storage tank and directly used in the combustion process.

Then the molecular sieve separated [2]methane/carbon dioxide would be purged or cleaned from its’ molecular sieve using a small volume of the compressed oxygen on a timed basis. The purged volume of methane/carbon dioxide/oxygen would be captured, compressed, and then processed at low pressure (<2bar) and ambient temperature through a photoelectrochemically powered tubular or sheet assembled, optically clear, covered methane “reformer” or “cracker” to make a compressed hydrogen and oxygen product with a small volume of residual of carbon dioxide as a contaminant. The [1]water vapor molecular sieve would be similarly purged with the excess [3]nitrogen gas on a timed basis with the balance of the nitrogen vented to atmosphere.

Commercially this atmospheric gas separation can be described as a VSA, PSA or VPSA any of which could work. Commercial vendors for the appropriate molecular sieve materials and the gas separation systems exist and should be thoroughly explored and then used as appropriate.

Maintenance needs are expected to be very low and should require nearly or no skilled labor to operate.

Commercially this system will be attractive from both a cost to construct and use (deploy) perspective especially when compared to either conventional or other unconventional (renewable) energy systems.

Alternatively, if the onboard hydrogen supply is too small, compressed methane or natural gas could be used although this would assume that some form of on demand logistic supply was available.

This author has previously specified use of magnetic bearings and transmissions for all applicable systems for similar, although smaller, applications. These are widely available and nicely sized for these applications which would eliminate most of the problems found with rotating machinery and their maintenance.

Again, this author does advocate close integration with other renewable energy generation and storage systems to increase supply optionality in the event of a national and / or regional grid outage of significant duration.

Railroad Locomotive Powergen Summary Notes

Goals:

- Goal 1: Nextgen mixed use rail prime mover is the innovation target for this effort.
- Goal 2: Nextgen mixed use rail prime mover must be capable of adoption within 5 years.
- Goal 3: Nextgen mixed use rail prime mover must be least cost, least risk.
- Goal 4: Nextgen mixed use rail prime mover' must be hydrocarbon combustion free.
- Goal 5: Nextgen mixed use rail prime mover must be robust for >1M mile service life.
- Goal 6: Nextgen mixed use rail locomotive must be capable of sustained 80+ mph operation.
- Goal 7: Nextgen mixed use rail locomotive must be operable in all topographies and climates.

- Goal 8: Nextgen mixed use rail trains must be capable of direct use of existing rail systems as is with no modifications.
- Goal 9: Speed of said rail trains shall only be limited by existing rail systems, topography, and weather events.

Notes

- All components must be capable of in place maintenance and replacement.
- All components or their associated critical duty items.
- All external power generated shall first charge on board batteries.
- All external power supplied shall be AC for train needs.
- All mission critical replacement components must be local stocked.
- All onboard control systems to be hardened 24VDC.
- All onboard power systems to be AC.
- CO2 sequestration for this application is contraindicated.
- Deployment of said system into full operation shall not be more than five minutes from a dead start with charged batteries (Insight).
- Atmospheric emissions shall be low temperature water vapor and trace amounts of NOx and CO2 well below background levels (Insight).
- H2/O2 expanding gas turbine power generation must be capable of supplying all on board power needs plus at least 25% of peak demand into the on-board storage battery / ultracapacitor banks.
- H2/O2 heat recovery shall be recycled for pre-heat and methane reformer needs then vented to atmosphere.
- Onboard AC /HVAC needs qualify for integration with a 6 - 10% inversion penalty.
- Power systems must be capable of 99%+ uptime operation.
- Power systems must be capable of sustained stand down or storage - on the order of years with no penalty (Insight).
- Power systems must be fully capable of offline no external access (Insight).
- Power systems shall be capable of 24/7/90 day operation before significant onboard maintenance.
- Molecular sieve materials must be fines removal pre-sieved then triple bagged with an appropriated desiccant for long-term on-board storage.
- PSA / VPSA or VSA must provide a 90%+ gaseous O2 product @ 2 bar pressure.
- PSA / VPSA or VSA must provide a 90%+ methane / CO2 blended product @ 2 bar pressure.

- PSA / VPSA or VSA must provide a 90%+ nitrogen product suitable for direct emission or other onboard uses such as fire suppression (Insight).
- Power systems must be easily integrated and coupled / decoupled with existing onboard drive systems.
- Power system turbines should be two or more output shaft capable to provide flexibility in drive and onboard power system integration and / or repair while at work.
- Said power systems batteries must be capable of providing at least +100% of peak demand for a 2-hour span (Insight).
- Power systems must be of unitized construction and capable of 4-hour changeout in depot (Insight).
- Said systems must provide enough power for mission critical sub systems.
- Startup external power supply shall be capable of 10-minute deployment support.
- Ultracapacitor components shall be capable of multiple recharges from the battery outputs.
- Ultracapacitor components shall be provided suitable for startup and local or brief operational needs (Insight).
- Ultracapacitor output shall be on board DC or AC voltage / amperage selectable (Insight).
- Prime mover' shall be hydrogen / oxygen EGT / electric traction motor design.
- Traction motors shall take power from on board high voltage batteries only (Insight).
- On board batteries shall be capable of meeting stand-alone operation for not least than 2 hours of sustained operation (Insight).
- Sustaining H2/O2 EGT combustion will require on-board compressed gaseous supply (Insight).
- Keeping the on-board batteries charged so that the traction motors can demand respond is the EGT' only goal (Insight).
- Batteries to be LiON or better and capable of sustained operation.
- Regenerative braking systems including dielectric fluid cooling shall be integrated (Insight).
- EGT exhaust heat can be used for environmental control of batteries and indirectly the traction motors on a pass / bypass basis (Insight).
- Traction motors must be AC not DC to mitigate resistor heat issues.
- Traction motors shall use a vaporizable dielectric fluid for heating / cooling.

- Radiators for dielectric fluid cooling may be externally mounted on the locomotive or on the following cars by serial connection (Insight).
- Heating / cooling of the cars shall be by radiator chilling or EGT heating of the non-hazardous dielectric fluid which may be palm oil or a derivative (Insight).
- On-board hydrogen generation shall be by incident solar reforming (previous – by author) serially mounted on the trailing cars roofs and / or the locomotive (Insight).
- Alternatively, externally supplied compressed hydrogen shall be provided and supplied from an on-board tank of appropriate design.
- On-board oxygen may be supplied from the incident solar reforming system as a product or more preferentially from a PSA supplied concentrated product (Insight).
- Alternatively, hydrogen may be solar reformed from a methane concentrate from a sequentially MOF configured on-board PSA (Insight).
- Said PSA (s) may be single but should be parallel installed for redundancy (Insight).
- Inlets for the PSA's shall be face mounted into on-board blower assemblies to feed the PSA MOF vessels (Insight).
- All on-board process heat exhausts shall be vertical and common in a single stack.
- Existing rail bed shall be used as is with as planned maintenance and replacements as needed (Insight).
- External control systems shall be optimized for both on time people and goods delivery at least cost and least risk.
- On board control systems shall include control and use of cooling / heating AC drive motor's dielectric fluid and continuous track monitoring for parallel spacing and displacement (Insight).
- Said integrated system shall be capable of 80+ mph operation on average throughout the continental system (Insight).
- Existing bridges must be modified to accept increased longitudinal and lateral stresses associated with 80+ mph operation.
- Existing bridges should have both entry and exit friction pads that have proven effective for handling longitudinal stresses.
- Existing bridges should have entry and exit rotational friction devices that have proven effective for handling lateral stresses.
- Existing bridges would then be capable of handling seismic events that are not judged catastrophic.

Conclusion

This unit, its various technologies and its intent are meant to solve the pressing need for a critical application - high speed least cost and risk for mixed use rail “trains”. It is meant to be easily fit and repeatedly deployed. It is meant to be “hack proof”. It can not only provide fully scaleable power (or much more) but also a significant volume and consistent source of potable drinking water for onboard use and heat. It only needs our atmosphere and some humidity to work which should not be too difficult to find.

Section 4.3: Inland container on barge propulsion and operations

Containers on Barge (COB) have proven to be cost and time efficient in the delivery of goods within a country's borders and slightly less so on a continental basis. Making this goods or freight (and people) delivery system yet more efficient and timely enough to compete with nextgen truck, rail and air delivery requires use of designs that offer on time delivery or efficiency for least cost. This can be done quickly. I see this coming to full fruition in an N+5 scenario which is Now + 20 years or ca 2040. A well-financed but domestic visionary can make it all happen.

The envisioned barge design and its freight load will be smaller than expected. This is logical when onboard renewable energy charged LiON battery driven waterjets are the propulsion method of choice. This is not a negative. Barge traffic would be frequent and tightly scheduled. These barges would be capable of operation on nearly all navigable water that would allow their width and length. Average draft would be 1.5 meters maximum or less. This powergen could be highly scaleable with modular units likely being developed in the 100 –250 Kw-h range available on a 24/7 basis for an integrated unit cost of ~ $500,000 – several million USD (less ancillary hardware that is pre-existing). Said units would be capable of sustained operation in all climactic and flow conditions with industry standard uptime and efficiency or much better. Commercial development monies can likely be provided by USDOE grants. Once decently proven up the private sector could conduct the rollout for a very substantial profit.

Container on Barge (COB) Concept

This author has previously specified use of magnetic bearings and transmissions for all applicable systems for similar, applications. These are widely available and nicely sized for these applications which would eliminate most of the problems found with rotating machinery and their maintenance.

Again, this author does advocate close integration with other renewable energy generation and storage systems to increase supply optionality in the event of a national and / or regional grid outage of significant duration.

As is usual for this author, others say it best with some notes by me:

Its citation: Bytnar, Linda, Andrew Chiu, Isabelle Frommann, Linda Gruwell, Lissa Guttman, and Wade Morgan. "Port of Pittsburgh practicum project." *Transportation research record* 1782, no. 1 (2002): 11-22.

“For the purpose of this discussion, **COB service** is defined as the use of barges to transport containers (hence Container on Barge – author) between water ports as part of the overall movement of a container of freight. The transport of containers by barge would also likely require that a container be moved by at least one other mode of transport for one or more segments of its journey. For example, a container of manufactured goods is transported from the factory to a port on a truck chassis and then transferred onto a barge. The barge carries the container to its destination port, where the container is unloaded and placed onto another trailer chassis and trucked to its destination. If serving a stacked container barge, a port must have the necessary infrastructure to move containers from ship, truck, or rail to the barge and vice versa.

At a minimum, this would require a crane for moving the container onto the barge and probably would require other equipment for moving containers around the port’s staging and storage areas. If containers were loaded onto the barge while on a trailer chassis, the equipment demands would be fewer, but the barge’s capacity would be less and the cost per container would be higher.

Additionally, ports must have the appropriate berths, channel, and dockside infrastructure to handle barges, tugs, and container-moving equipment.

However, the equipment demands for moving containers by barge are not as great as moving containers by ship, because barge volumes are usually smaller and loading a barge does not create the same height and width issues for cranes.

A **COB network** would be defined, in this discussion, as regularly scheduled COB services that move commodity- or good-filled containers by barge to, from, or between Texas (read “any” – this author) ports with at least some routes having two or more competitive COB carriers. A COB network, in this discussion, also means that COB operators can effectively compete with truck and rail modes.

At present, there are several locations around the world where COB operators are providing service. The most successful of these operations is in northern Europe, particularly in the Netherlands and in Germany along the Rhine River. In Rotterdam trucks now carry less than 50% of the containers to and from the port

because of the growing share of containers that are transported by barge. In Antwerp approximately 1.52 million containers were moved by barge in 2000, and between the ports of Rotterdam and Antwerp, 850,000 20-ft equivalent units (TEUs) were shipped in 2000. In Germany, the Rhine River has become the primary route for containers, and barge operators provide scheduled, frequent service.

COB operations exist in the United States, as well, located along the Columbia and Snake Rivers in Washington and Idaho, along the middle Atlantic Coast, and in Texas. There are also plans to develop COB service in the northeastern United States. Along the Columbia and Snake Rivers, barges carried more than 50,000 containers in 2000 between the port of Portland and the ports of Lewiston, Pasco, Umatilla, and Morrow-Boardman.

Several attempts have been made to develop COB service along the Mississippi River, but none of these attempts has been sustainable. The last COB service to operate along the Mississippi River carried refrigerator compressors that were unloaded from Brazil at the port of New Orleans and shipped upstream to Illinois, where they were then transported to a factory in Indiana. This COB service ended in the mid-1990s (Whirlpool / Evansville – this author).

The development of a container-on-barge (COB) network is a worthwhile proposal because there are several benefits that could be realized from moving containers on barge versus moving them by truck or rail. First, the state's roadways are experiencing increasing levels of congestion that have been exacerbated by placing more trucks on the road to serve a growing population and economy. Although the exact number depends on a barge's size, an average single barge could remove 58 trucks from Texas (any state – this author) roadways. **Second, barges are more fuel efficient than truck or rail. A single gallon of fuel can move a ton of commodities 514 miles by barge, versus moving the same ton 59 miles by truck and 202 miles by rail.** Third, because barges use less fuel than truck or rail, they introduce fewer pollutants into the atmosphere. For example, 10 million fewer tons of carbon dioxide were released into the atmosphere because commodities were transferred by barge instead of by rail (1). Thus, COB service could offer opportunities to lower exhaust emissions in air sheds that do not meet U.S. Environmental Protection Agency criteria for air quality. Fourth, railways have had great difficulty improving their service after the recent takeovers and mergers. COB service would offer shippers another choice for moving freight, and that could increase competition. Finally, COB service could expand the reach of

smaller ports with poor landside access by connecting them to areas outside their regions.

Jones Act Restrictions

The Merchant Marine Act of 1920, more commonly known as the Jones Act, prevents foreign-owned shipping companies and foreign built vessels from operating between U.S. ports." This, then, requires domestic ownership – this author.

Design Concept

This author advocates the use of a semi-submerged shallow draft hull shape with a bulbous nose and slightly V shaped hull bottom for hydrodynamic efficiency at low speeds. I particularly advocate the use of a RHIB design concept with imbedded articulated thrusters at bow, midships and stern along with dual electric powered waterjet propulsion system. Solar PV and wind turbine(s) shall be used to keep the onboard LiON battery system charged.

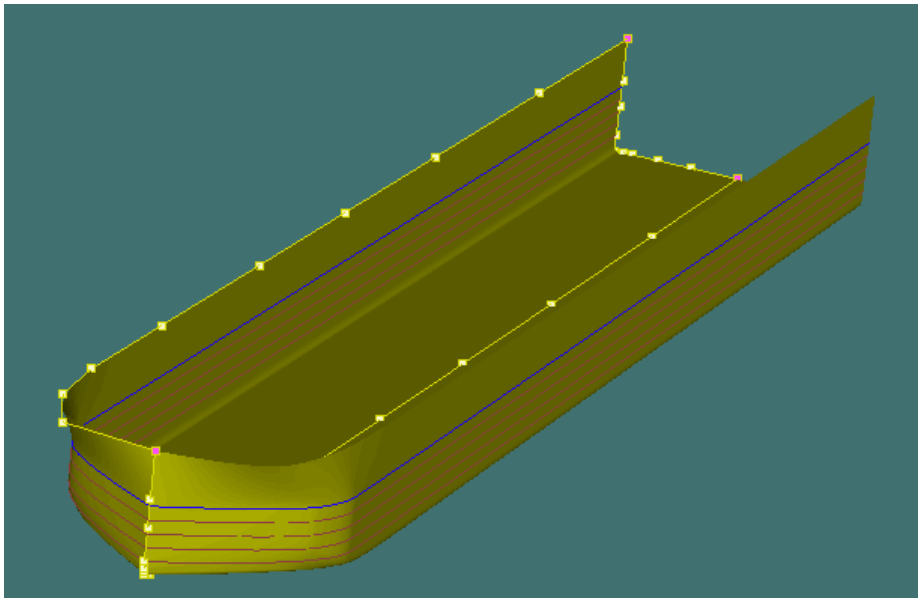
A description of an RHIB is just below. Its' citation: Wikipedia contributors, "Rigid inflatable boat," Wikipedia, The Free encyclopedia, https://en.wikipedia.org/w/index.php?title=Rigid_inflatable_boat&oldid=1105447631 (accessed August 22, 2022).

"A **rigid inflatable boat** (**RIB**), also **rigid-hull inflatable boat** or **rigid-hulled inflatable boat** (**RHIB**), is a lightweight but high-performance and high-capacity unsinkable boat constructed with a rigid hull bottom joined to side-forming air tubes that are inflated with air to a high pressure so as to give the sides resilient rigidity along the boat's topsides. The design is stable, light, fast and seaworthy. The inflated collar acts as a life jacket, ensuring that the vessel retains its buoyancy, even if the boat is taking on water. The RIB is an evolutionary development of the inflatable boat with a rubberized fabric bottom that is stiffened with flat boards within the collar to form the deck or floor of the boat.

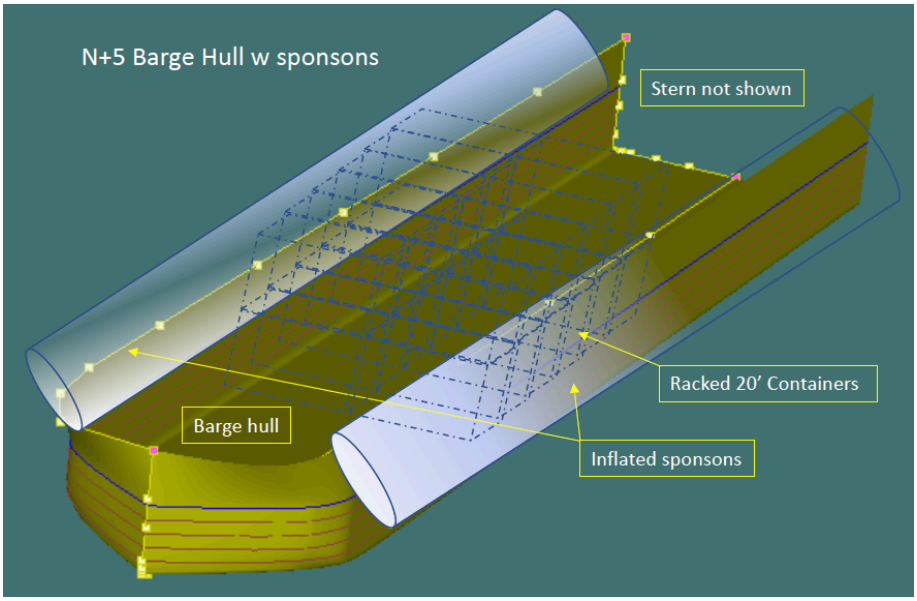
Uses include work boats (supporting shore facilities or larger ships) in trades that operate on the water, military craft, where they are used in patrol roles and to transport troops between vessels or ashore, and lifeboats."

Further, the author advocates the following layout of the barge by shape and container stacking arrangement and thrust systems:

Barge Hull Form

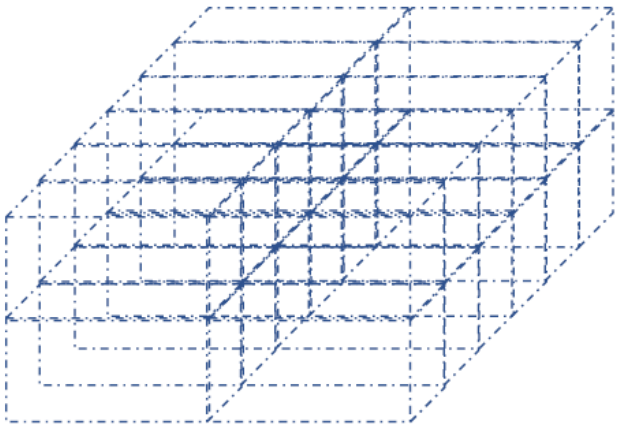


As can be seen above the hull form is semi-submerged with a bulbous bow and flat transom stern. If offer hydrodynamic efficient at relatively low speeds and offer high weight freight capacity with low cost to construct. This author advocates FRP hull fabrication with imbedded basalt or boron fibers for strength.

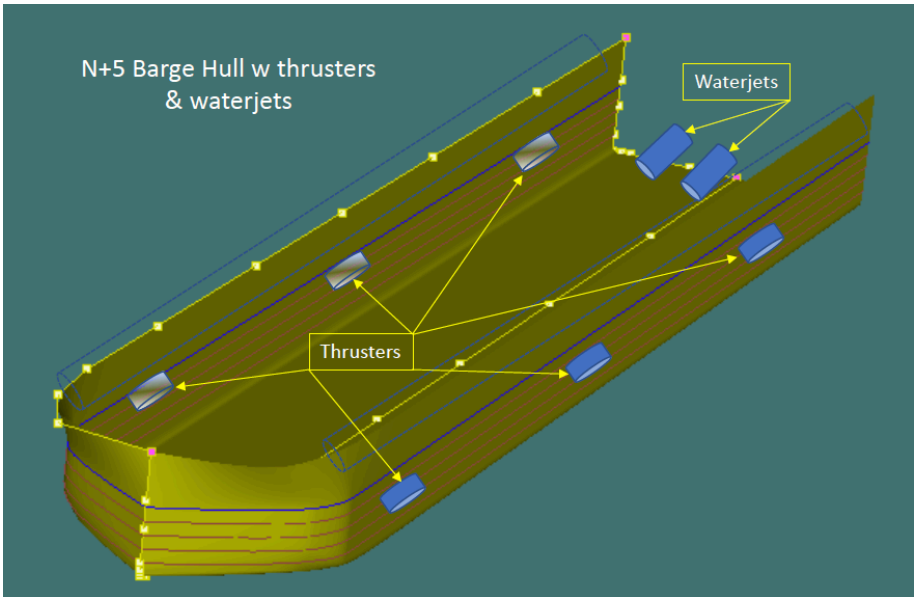


Sponson are meant to be air inflated or deflated on a near continuous basis over a very long design life measured in decades for low-cost replacement.

Typical 20' Container Rack
w 24 containers



ISO standard 20' containers are this author's design standard. Transverse beam to beam loading offers operation stability and the ready use of shore-based straddle carriers.



Shallow draft waterjets of a standard design with DC motors with an inlet through hull below the gunwale but not the bottom would work best. Inlets must be screened and capable of being cleaned from onboard.

Summary Notes

Goals:

- Goal 1: Nextgen mixed use barge must be capable of adoption within 15 years.
- Goal 3: Nextgen mixed use barge must be least cost, least risk.
- Goal 4: Nextgen mixed use barge must be hydrocarbon combustion free.
- Goal 5: Nextgen mixed use barge must be robust for >1M mile service life.

Notes:

- All components must be capable of in place maintenance and replacement.
- All components or their associated critical duty items.
- All external power generated shall first charge on board batteries.
- All external power supplied shall be DC for barge needs.
- All mission critical replacement components must be local stocked.
- All onboard control systems to be hardened 24VDC.
- All onboard power systems to be DC.

- Deployment of said system into full operation shall not be more than five minutes from a dead start with charged batteries (Insight).
- Power systems must be capable of 99%+ uptime operation.
- Power systems must be capable of sustained stand down or storage - on the order of months with no penalty (Insight).
- Power systems must be fully capable of offline operation with no external access (Insight).
- Power systems shall be capable of 24/7/90 day operation before significant onboard maintenance.
- Power systems must be easily integrated and coupled / decoupled with existing onboard drive systems.
- Said power systems batteries must be capable of providing at least +100% of peak demand for a 12-hour span (Insight).
- Power systems must be of unitized construction and capable of 4-hour changeout in depot (Insight).
- Said systems must provide enough power for mission critical sub systems.
- Startup external power supply shall be capable of 10-minute deployment support.
- Ultracapacitor or LiON components shall be capable of multiple recharges from the battery outputs.
- Ultracapacitor components shall be provided suitable for startup and local or brief operational needs (Insight).
- Ultracapacitor output shall be on board DC and have amperages selectable at need (Insight).
- Onboard motors shall use a vaporizable dielectric fluid for heating / cooling.
- Radiators for dielectric fluid cooling may be externally mounted on the barge gunwale or transom by serial connection (Insight).
- Heating / cooling of the containers shall be by radiator chilling or EGT heating of the non-hazardous dielectric fluid which may be palm oil or a derivative (Insight).
- All on-board process heat exhausts shall be vertical and common in a single stack.
- External control systems shall be optimized for both on time people and goods delivery at least cost and least risk.
- Non-standard hull design w rapid variable draft desirable for bottom clearance and flow conditions plus loading / unloading and near dock maneuvering (Insight).

- RIB hull with draft maintained by inflation / deflation of air bladders (Insight).
- Multiple articulated thrusters at stern, bow and amidships.
- RE powered via LiON batteries powered via solar PV and wind turbine (HAWT not VAWT) as horizontal axis wind turbine(s).
- LiON batteries powered propulsion by stern mounted water jets.
- NO EGT (expanding gas turbine) for this application for safety and mechanical simplicity requirements.
- Speed shall be current plus 2-3kn down or up.
- GC or Basalt fiber or Boron fiber for FRP hull and inflatable sponsons.
- Shallow draft is a must for inland freight barges.
- Draft to be <1.5m in service which shall determine hull sizing.
- 20' ISO container to be standard sizing for packing / picking ease.
- All containers to be loaded perpendicular to direction of travel - e.g., beam to beam (Insight).
- Automated port load / unload via straddle carrier highly desirable.
- Load / unload cycle shall not exceed 120 minutes.
- Stacks of ISO containers to be 2 or 3 high by 2 wide on a pre-loaded pack pallet of a standard configuration (Insight).
- RFID tag or equivalent on container, contents and manifest.
- Staffing (if any) to be 3 or 6 personnel on 8 on /8 off schedule (Insight).
- Between 24 and 30 containers shall fit the barge to capacity.
- Intermodal packing and packaging shall be consistent with no variance.
- People may be transported from port to port in specialized containers on upper decking only.
- End to end intermodal freight business model is highly desirable and would be highly disruptive.
- Jones Act precludes foreign ownership.
- E Musk type vision can make this happen not J Bezos' incremental growth vision.

Conclusion

This stepchange concept and its various technologies, its design, operation, and intent are meant to solve the pressing need for a critical application – consistent on-time, least cost and risk for mixed use barge “trains” for use within a fully integrated intermodal freight system.

Section 4.4: Nextgen concrete roadbeds

Concrete and its varied components have been used for infrastructure construction for 2,500+ years with varying levels of success. The Roman Empire innovated a hydraulic concrete formula that worked for their infrastructure needs especially well and those infrastructure works are still in use today – 2,500 years later. Our own contemporary formula's do not typically work as well and last for roughly 30 – 100 years. Answering "what", "why" and "how" to relearn this apparent lost technology and allow our modern infrastructure needs to capture the longevity of the old formula using contemporary components and a novel reaction method for least cost, least risk is the intent of this simple paper.

Further, this author proposes that CO2 capture and captured and compressed CO2 from cement manufacturing or other atmospheric separation sites be used in nextgen concrete construction on a global basis. It can then be directly reutilized at point of commercial use such as large structures as building or roadbeds by OTR truck delivery from point of capture. This simple idea captures having the ability to least cost / no risk dissolve said CO2 into the water binder at saturation at point of use by using commonly available pipe and continuously stirred reactors. Said "carbonated" water shall then act as a catalyst to form a superior performance concrete that demonstrates superior wear and compression ability. Especially when used with this author's nextgen concrete formula detailed later in this paper. This simple concept of use would allow large scale carbon fixation on a global basis with full mitigation of concrete manufacture' issue with CO2 emissions and substantial mitigation of atmospheric carbon thereby beneficially abating a primary cause of climate change. Further there is no scientific or engineering reason why this can't be easily done.

Background

Answering some basic questions about definitions for what concrete is and distinctions for its components that are in common use (by others). Its' citation: Clark, Edward, Monika Bleszynski, Frank Valdez, and Maciej Kumosa. "Recycling carbon and glass fiber polymer matrix composite waste into cementitious materials." *Resources, Conservation and Recycling* 155 (2020): 104659.

A. *Concrete* is a composite material that consists of a mixture of hydraulic cement, aggregates, and water, with or without admixtures, fibers, or other cementitious materials.
Hydraulic cement is cement that sets and hardens by chemical reaction with water (hydration) and is capable of doing so under water (ACI 225R). The hydration reactions result in the formation of a hard-solid mass. The most widely used hydraulic cement is Portland cement. Other kinds of hydraulic cement include blended cements and ground granulated blast-furnace slag (ACI 233R). Pozzolans, both natural (ACI 232.1R) and artificial (fly ash, ACI 232.2R, and silica fume, ACI 234R) are often used as a cementitious ingredient of concrete.
Mortar is a mixture of cement paste and fine aggregate; in fresh concrete, the material occupying the interstices among particles of coarse aggregate; in masonry construction, joint mortar may contain masonry cement, or may contain hydraulic cement with lime (and possibly other admixtures) to afford greater plasticity and workability than are attainable with standard Portland cement mortar.
Grout is a mixture of cementitious materials and water, or other binding medium, with fine aggregate.

References: SP-1(02); CT-18; ACI 225R-19; ACI 233R-03; ACI 232.1R-12; ACI 232.2R-03; ACI 234R-06; E-1(16); E3-13
Topics in Concrete: Concrete Fundamentals; Grout; Materials”

Then answering the question of “why” modern concrete fails so badly (by others):

The cracks are starting to show. Dean McCartney, Author provided

The problem with reinforced concrete

June 17, 2016, 1.18am EDT

Author

1. **Guy Keulemans**
Lecturer, UNSW

Disclosure statement

Guy Keulemans does not work for, consult, own shares in or receive funding from any company or organization that would benefit from this article, and has disclosed no relevant affiliations beyond their academic appointment.

Partners

UNSW provides funding as a member of The Conversation AU.

View all partners

We believe in the free flow of information

Republish our articles for free, online or in print, under a Creative Commons license.

Republish this article

By itself, concrete is a very durable construction material. The magnificent Pantheon in Rome, the world's largest unreinforced concrete dome, is in excellent condition after nearly 1,900 years. And yet many concrete structures from last century – bridges, highways, and buildings – are crumbling. Many concrete structures built this century will be obsolete before its end.

Given the survival of ancient structures, this may seem curious. The critical difference is the modern use of steel reinforcement, known as rebar, concealed within the concrete. Steel is made mainly of iron, and one of iron's unalterable properties is that it rusts. This ruins the durability of concrete structures in ways that are difficult to detect and costly to repair.

While repair may be justified to preserve the architectural legacy of iconic 20th-century buildings, such as those designed by reinforced concrete users like Frank Lloyd Wright, it is questionable whether this will be affordable or desirable for the vast majority of structures. The writer Robert Courland, in his book Concrete Planet, estimates that repair and rebuilding costs of

concrete infrastructure, just in the United States, will be in the trillions of dollars – to be paid by future generations.

Old bridges need new money to replace. Phil's 1stPix/Flickr.com, CC BY-NC

Steel reinforcement was a dramatic innovation of the 19th century. The steel bars add strength, allowing the creation of long, cantilevered structures and thinner, less-supported slabs. It speeds up construction times because less concrete is required to pour such slabs.

These qualities, pushed by assertive and sometimes duplicitous promotion by the concrete industry in the early 20th century, led to its massive popularity.

Reinforced concrete competes against more durable building technologies, like steel frame or traditional bricks and mortar. Around the world, it has replaced environmentally sensitive, low-carbon options like mud brick and rammed earth – historical practices that may also be more durable.

Early 20th-century engineers thought reinforced concrete structures would last a very long time – perhaps 1,000 years. In reality, their life span is more like 50-100 years, and sometimes less. Building codes and policies generally

require buildings to survive for several decades, but deterioration can begin in as little as 10 years.

Many engineers and architects point to the natural affinities between steel and concrete: they have similar thermal expansion characteristics, and concrete's alkalinity can help to inhibit rust. But there is still a lack of knowledge about their composite qualities – for example, in regard to sun-exposure-related changes in temperature.

The many alternative materials for concrete reinforcement – such as stainless steel, aluminium bronze, and fibre-polymer composites – are not yet widely used. The affordability of plain steel reinforcement is attractive to developers. But many planners and developers fail to consider the extended costs of maintenance, repair, or replacement.

Cheap and effective, in the short term at least. Luigi Chiesa/Wikimedia Commons, CC BY-SA

There are technologies that can address the problem of steel corrosion, such as cathodic protection, in which the entire structure is connected to a rust-

inhibiting electric current. There are also interesting new methods to monitor corrosion, by electrical or acoustic means.

Another option is to treat the concrete with a rust-inhibiting compound, although these can be toxic and inappropriate for buildings. There are several new non-toxic inhibitors, including compounds extracted from bamboo and bacterially derived "biomolecules".

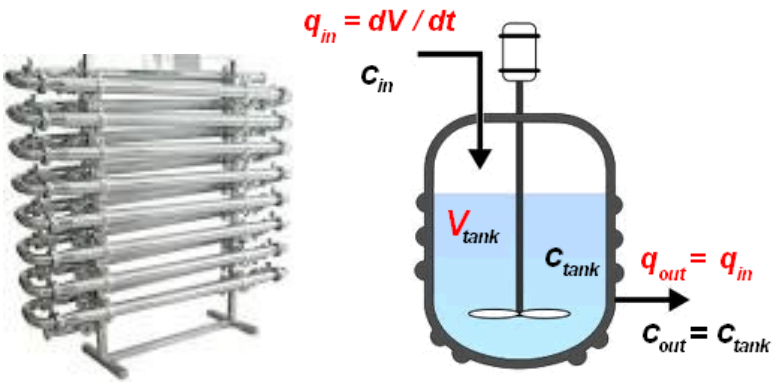
Fundamentally, however, none of these developments can resolve the inherent problem that putting steel inside concrete ruins its potentially great durability.

The environmental costs of rebuilding

This has serious repercussions for the planet. Concrete is the third-largest contributor to carbon dioxide emissions, after automobiles and coal-fuelled power plants. Cement manufacturing alone is responsible for roughly 5% of global CO_2 emissions. Concrete also makes up the largest proportion of construction and demolition waste and represents about a third of all landfill waste.

Recycling concrete is difficult and expensive, reduces its strength and may catalyse chemical reactions that speed up decay. The world needs to reduce its concrete production, but this will not be possible without building longer-lasting structures.

"Again, to reiterate, this author proposes that CO2 capture and captured and compressed CO2 from cement manufacturing or other atmospheric separation sites be used in nextgen concrete construction on a global basis. It can then be directly reutilized at point of commercial use such as large structures as building or roadbeds by OTR truck delivery from point of capture. This simple idea captures having the ability to least cost / no risk dissolve said CO2 into the water binder at saturation at point of use by using commonly available pipe and continuously stirred reactors. Said "carbonated" water shall then act as a catalyst to form a superior performance concrete that demonstrates superior wear and compression ability. Especially when used with this author's nextgen concrete formula detailed later in this paper. This simple concept of use would allow large scale carbon fixation on a global basis with full mitigation of concrete manufacture' issue with CO2 emissions and substantial mitigation of atmospheric carbon thereby beneficially abating a primary cause of climate change. Further there is no scientific or engineering reason why this can't be easily done. A typical pipe reactor and CSTR diagram are just below:"



“The pipe reactor (above to the left) and the continuously stirred tank reactor to its right have been used for gas dissolution and mixing in the chemical processing industry for at least 40 years. They are not magic – author.”

Rebar reclamation: an expensive job. Anna Frodesiak/Wikimedia Commons

In a recent paper, I suggest that the widespread acceptance of reinforced concrete may be the expression of a traditional, dominant, and ultimately destructive view of matter as inert. But reinforced concrete is not really inert.

Concrete is commonly perceived as a stone-like, monolithic, and homogeneous material. In fact, it is a complex mix of cooked limestone, clay-like materials, and a wide variety of rock or sandy aggregates. Limestone itself is a sedimentary rock composed of shells and coral, whose formation is influenced by many biological, geological, and climatological factors.

This means that concrete structures, for all their stone-like superficial qualities, are actually made of the skeletons of sea creatures ground up with rock. It takes millions upon millions of years for these sea creatures to live, die and form into limestone. This timescale contrasts starkly with the life spans of contemporary buildings.

Steel is often perceived to be inert and resilient too. Terms such as “Iron Age” suggest an ancient durability, although Iron Age artefacts are comparatively rare precisely because they rust. If construction steel is visible, it can be maintained – for instance, when the Sydney Harbour Bridge is repeatedly painted and repainted.

However, when embedded in concrete, steel is hidden but secretly active. Moisture entering through thousands of tiny cracks creates an electrochemical reaction. One end of the rebar becomes an anode and the other a cathode, forming a “battery” that powers the transformation of iron into rust. Rust can expand the rebar up to four times its size, enlarging cracks and forcing the concrete to fracture apart in a process called spalling, more widely known as “concrete cancer”.

Concrete cancer: not pretty. Sarang/Wikimedia Commons

I suggest that we need to change our thinking, to recognize concrete and steel as vibrant and active materials. This is not a case of changing any facts, but rather of re-orientating how we understand and act on those facts. Avoiding waste, pollution and needless rebuilding will require thinking well beyond disciplinary conceptions of time, and this is especially true for the building and construction industries.

The collapsed civilisations of the past show us the consequences of short-term thinking. We should focus on building structures that stand the test of time – lest we end up with hulking, derelict artefacts that are no more fit for their original purpose than the statues of Easter Island."

Nextgen Cement Concept

Capturing the high performance (tensile, compression and deformation strength) of the Roman Empire's hydraulic cement matrix which cured readily in saltwater and capturing our current society's need for both a landbased or terrestrial and marine cement of superior performance and longevity can seem hard to do because nobody's apparently come close.

In a strong sense I am asking to find the way to increase our version of concrete's strength using commonly available components and I also do not want to use reinforcing rod (re-rod) steel because of its corrosion issues. A very tall order but I do think it can be done with an open mind and some perseverance.

Several very recent studies have been done that point the way. Not one of them offers an integrated recipe or formula to follow. I really don't understand why that might be the case but can certainly make a guess.

I've assembled a "recipe" with some broad instructions that should be helpful (I hope so). Not least the recipe will yield a cement matrix that will perform at least as well as today's cement. I strongly suspect it will outperform it and may well offer a least cost, least risk solution along with my own take on IP that might be captured as well. That recipe and notes are below:

- Aligned carbon nanotubes should be used - whether MW or SW will make no difference (Insight).
- Quicklime (CaO) shall be used as the hydrated cement' primary binder.
- Carbon dioxide (CO2) saturated water shall be used as the hydration agent.
- Aluminum shall be used as a water supplement to promote tobermorite formation as sodium aluminum phosphate (Insight).
- Water shall not be softened (Insight).
- Water as the matrix or hydration agent or solution shall be alkaline and preferably with a pH of 8 +/- 0.5 in its initial state before any cement blending (Insight).
- Water shall be visually free of organic contaminants.
- Alignment of carbon nanotubes shall be done by mechanical mixing in water after the surfactant addition (Insight).

- Carbon nanotubes shall be added in the range of 0.1 - 0.5% by overall weight of the final mixture and preferably in the 0.1 - 0.25% range (Insight).
- Dispersion of the carbon nanotubes (CNT) shall be accomplished by inducing hydrophilicity of the CNT with a small, applied voltage of 2.0V to the initial water / CNT mix with phase and wattage not important (Insight).
- Alignment of the CNT in the initial water mix must be done by mechanical mixing until visually thoroughly dispersed (Insight).
- Use of oxidized calcium sulfate as an additive to the cement binder' dry blend is contraindicated (Insight).
- The soluble aluminum salt as sodium aluminum phosphate shall be added to the initial water blend before the CNT addition (Insight).
- Aggregate type and size used shall be to common standard.
- Aggregate used must be pre-washed until free of visible dirt and organic contaminants and then blended into the cement binder.
- Use of a non-ionic surfactant should be added to manufacturer' specification before the addition of the aluminum salt and CNT to the water matrix solution (Insight).
- Concrete cure time will be to industry standard for time and temperature.
- Mechanical performance shall be like hydraulic concrete or better without the need for continuous wetting unless in an arid climate (Insight).
- Otherwise, industry standards for mix blends and mixing time and energy shall not change.
- Water soluble iron salts such as iron sulfate or thirdly ferrous iron may be used as a substitute for calcium aluminum phosphate in extraordinary circumstances such as extremely arid or near vacuum environments (Insight).
- Transport of pre-blended and mixed concrete to a job site from a remote location is contraindicated due to this blend’s reaction chemistry and its exothermic reaction (Insight).
- Point of use blending is very easy and would use water, CO2 and dry cement tanker delivery with on-site blending and mixing using commonly available hardware that is easily setup and broken down as needed.

Section 4.5: Non-hydrocarbon air freight concept

A relevant perspective by others that I picked out of a recent “Foreign Affairs” article:

“Climate change is often described as a “wicked problem” meaning that it resists easy definition and defies conventional solutions. It transcends political boundaries and cannot be solved by a single country, but international governance is a weak substitute. It is a collective – action problem that demands a collective solution, but it has instead led to a great deal of finger pointing.” Also, “In short, humanity uses the atmosphere as a free dumping ground for pollutants, and deeply vested interests resist changing that.”

A sizeable resource and research publication library has been assembled and should be used accordingly if interest proves favorable.

Air transport has proven to be time efficient in the delivery of goods on a global basis. Making these goods (and people) delivery system yet more efficient and timely enough to capture a complementary least cost integration with high-speed rail and nextgen ocean transport requires use of robust, simple, and efficient design concepts that offers least cost and least risk. Going faster and higher with yet more tonnage on board isn’t a viable answer especially when our society is going through wrenching changes due to climate change, pandemics and increasing resource scarcity. This concept I am outlining can be proven up quickly and deployed very broadly to best effect. At least that is my belief.

The priority would be the development of a replacement air transport powergen and thrust system capable of sustained reasonably high-speed transit with little downtime. This powergen would be highly scaleable with modular units likely being developed in the 0.5 –15 MW-h (or much more) range. High amperage AC (or DC) power would be available on a 24/7 basis for an integrated unit cost of ~ $300,000 – several million USD. Said units would comprise powergen w PSA, STOL/VTOL nozzles, battery pack and cruise impellers. It would also be capable of sustained operation in all climactic conditions with industry standard uptime and efficiency or much better. Commercial development monies can likely be provided by USDOE or USDOD grants. Once decently proven up the private sector could conduct the rollout for a very substantial profit.

Reiterating, the target application for this summary report is least cost power generation (powergen) for air transport needs that replaces the need for hydrocarbon combustion systems for propulsion and their other onboard uses.

This powergen system may also occasionally require a small volume of startup only dedicated compressed oxygen and hydrogen supplied by conventional means which are or can be made easily and widely available at depots worldwide.

Replacing conventional powergen and propulsion systems for a least cost, least risk powergen and propulsion system offers obvious benefits. Affording to do a large-scale program conversion of this type can be easily done using the energy tax model this author has outlined many times in the recent past.

The sun doesn't have to shine, the wind doesn't have to blow, and the people and goods get delivered in a timely manner and safely.

Concept

This power generation system will create its own fuels from atmospheric gases (hydrogen and oxygen) and then via a proven hydrogen / oxygen expanding gas combustion turbine directly coupled to a power generator that will, in turn, charge a dedicated bank of sized for the application batteries (think TeslaWall). Said batteries will supply the AC or DC local onboard needs including propulsion on a demand basis. The system can be designed for 24/7/365-day operation with the promise of uptime exceeding 99%.

The forms of "emission" from this power generation system would be excess to need heat as steam seen as a contrail during cruise conditions. Takeoff or other high-speed operations may see some small amounts of NOx emissions as well.

Avoiding power generation output issues that can vary substantially with both ambient temperature, elevation and humidity requires the use of a high alloy intercooled two or three or more compressor stage set of serially piped LOPR turbines with supplemental water injection as needed. I do also advocate that these turbine sets be installed in parallel multiples (probably two) to provide scaleable power and necessary backup working from an excess of caution.

An illustration of the basic process also with some notes by others is below:

"PROCESS DESCRIPTION OF A GRAZ CYCLE PLANT FOR HYDROGEN COMBUSTION

Figure 1 shows the principal flow scheme of the Graz Cycle plant for hydrogen combustion, and Fig. 2 the associated temperature-entropy (T-s) diagram generated by the software IPSEpro. The plant is based on a proposal by Jericha [9] and consists basically of a high-temperature Brayton cycle and a low-temperature Rankine cycle – a combined cycle. The Brayton part consists of the combustion chamber (CC), the high-temperature turbine (HTT) and the compressors (C1/C2). The Rankine steam loop consists of the heat recovery steam generator (HRSG), high-pressure steam turbine (HPT), low pressure steam turbine (LPT), condenser, condensate pump, deaerator and finally the feed pump supplying high pressure water to the HRSG.

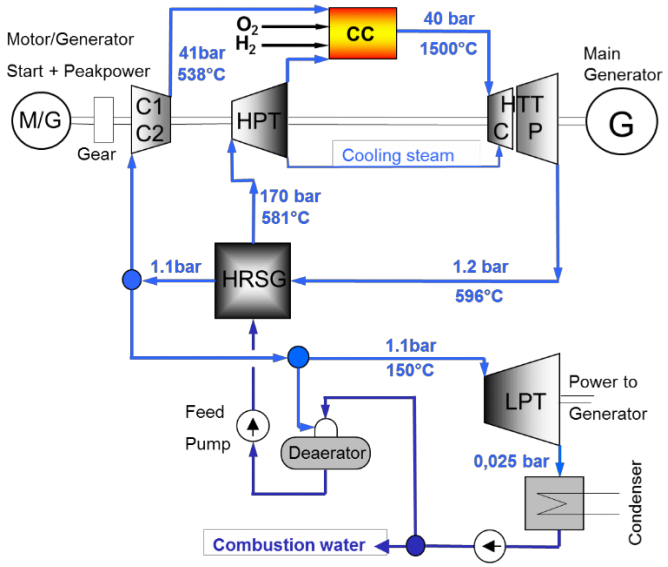


Fig. 1: Principal flow scheme of the Graz Cycle for hydrogen/oxygen combustion"

Maintaining consistent and predictable power generation is key for this process to work. The key is aggressive heat management as shown above.

Put another way: "Generally, unlike the heat rate, the net power output from a gas turbine decreases with an increase of the ambient air temperature. This is due to reduced net power output, which is directly proportional to the air mass flow rate; net power produced decreases when the ambient air temperature increases.

Practically, a 25% loss of the rated power capacity of the gas turbine at ISO conditions as the ambient temperature reaches 40 °C is reported."

Given that this process issue as described above can be easily overcome by design then this concept then becomes compelling given the application at hand.

In all instances all sub-systems are well proven. No new technology is required.

This author knows that a consistent and appreciable volume of relatively pure H2 / O2 are needed. My concept description for this is just below as both a simple drawing and in text (see next page):

A blower driven raw atmosphere intake contacts a set of three sequentially mounted molecular sieves that would remove [1]water vapor, [2]methane/carbon dioxide and [3]nitrogen from the intake atmosphere volume. The “concentrated” downstream “gas” would be 90%+ oxygen would be compressed in a storage tank and directly used in the combustion process.

Then the molecular sieve separated [2]methane/carbon dioxide would be purged or cleaned from its’ molecular sieve using a small volume of the compressed oxygen on a timed basis. The purged volume of methane/carbon dioxide/oxygen would be captured, compressed, and then processed at low pressure (<2bar) and ambient temperature through a photoelectrochemically powered tubular or sheet assembled, optically clear, covered methane “reformer” or “cracker” to make a compressed hydrogen and oxygen product with a small volume of residual of carbon dioxide as a contaminant. The [1]water vapor molecular sieve would be similarly purged with the excess [3]nitrogen gas on a timed basis with the balance of the nitrogen vented to atmosphere.

Commercially this atmospheric gas separation can be described as a VSA, PSA or VPSA any of which could work. Commercial vendors for the appropriate molecular sieve materials and the gas separation systems exist and should be thoroughly explored and then used as appropriate.
Maintenance needs are expected to be very low and should require nearly or no skilled labor to operate.

Commercially this system will be attractive from both a cost to construct and use (deploy) perspective especially when compared to either conventional or other unconventional (renewable) energy systems.

Alternatively, if the onboard hydrogen supply is too small, compressed methane or natural gas could be used although this would assume that some form of on demand quality fuel logistic supply was available.

This author has previously specified use of magnetic bearings and transmissions for all applicable systems for similar, although smaller, applications. These are widely available and nicely sized for these applications which would eliminate most of the problems found with rotating machinery and their maintenance.

Again, as a sidebar statement, this author does advocate close integration with other renewable energy generation and storage systems to meet some takeoff or landing scenarios. This increases supply optionality in the event of a national and / or regional grid outage of significant duration.

Below is a simple summary chart of flight regime versus propulsion type for the envisioned air transport:

Flight Regime	EGT1 Subsonic	EGT1 Turbo Impeller	EGT1 Battery Impeller
Takeoff:			
STOL	*		
VTOL			
Conventional		*	
Climb:			
Rapid			
Slow	*		
Conventional		*	
Cruise			
FR1			*
FR2		*	
Loiter			
Long		*	
Short			*
Conventional			*
Descent			
Rapid		*	

Gradual			*
Conventional			*
Landing			
STOL	*		
VTOL			
Conventional		*	
Arrested			*

Air Transport Powergen Summary Notes

Goals:

- Goal 1: Nextgen +5 mixed use air transport prime mover is the innovation target for this effort.
- Goal 2: Nextgen +5 mixed use air transport prime mover must be capable of adoption within 15 years.
- Goal 3: Nextgen +5 mixed use air transport prime mover must be least cost, least risk.
- Goal 4: Nextgen +5 mixed use air transport prime mover' must be hydrocarbon combustion free.
- Goal 5: Nextgen +5 mixed use air transport prime mover must be robust for >1M mile service life.
- Goal 6: Nextgen +5 mixed use air transport must be capable of sustained 0.5 mach operation or slightly less operation in all climactic conditions.
- Goal 7: Nextgen +5 mixed use air transport must be operable in all topographies and climates.
- Goal 8: Nextgen +5 mixed use air transports must be capable of direct use of existing air transport signal and control systems as is with no modifications.

Notes:

- All components must be capable of in place maintenance and replacement.
- All external power generated shall first charge on board batteries.
- All mission critical replacement components must be local stocked.
- All onboard control systems to be hardened 24VDC.
- All onboard power systems to be AC (or DC with debate).
- CO2 sequestration for this application is contraindicated.

- Deployment of said system into full operation shall not be more than five minutes from a dead start with charged batteries (Insight).
- Atmospheric emissions shall be low temperature water vapor and trace amounts of NOx and CO2 well below background levels (Insight).
- H2/O2 expanding gas turbine power generation must be capable of supplying all on board power needs plus at least 25% of peak demand into the on-board storage battery / ultracapacitor banks.
- H2/O2 heat recovery shall be recycled for pre-heat and methane reformer needs then vented to atmosphere.
- Onboard AC /HVAC needs qualify for integration with a 6 - 10% inversion penalty.
- Methane cracker must be capable of providing at least a 50%+ hydrogen product @ 2 bar pressure (Insight).
- Power systems must be capable of 99%+ uptime operation with planned PM only.
- Power systems must be capable of sustained stand down or storage - on the order of years with no penalty (Insight).
- Power systems must be fully capable of offline no external access (Insight).
- Power systems shall be capable of 24/7/90 day operation before significant onboard maintenance.
- Molecular sieve materials must be fines removal pre-sieved then triple bagged with an appropriated desiccant for long-term on-board storage.
- PSA / VPSA or VSA must provide a 90%+ gaseous O2 product @ 2 bar pressure.
- PSA / VPSA or VSA must provide a 90%+ methane / CO2 blended product @ 2 bar pressure.
- PSA / VPSA or VSA must provide a 90%+ nitrogen product suitable for direct emission or other onboard uses such as fire suppression (Insight).
- Power systems must be easily integrated and coupled / decoupled with existing onboard drive systems.
- Power system turbines should be two or more output shaft capable to provide flexibility in drive and onboard power system integration and / or repair while at work.
- Said power systems batteries must be capable of providing at least +100% of peak demand for a 2-hour span (Insight).
- Power systems must be of unitized construction and capable of 4-hour changeout in depot (Insight).
- Said systems must provide enough power for mission critical sub systems.

- Startup external power supply shall be capable of 10-minute deployment support.
- Ultracapacitor components shall be capable of multiple recharges from the battery outputs.
- Ultracapacitor components shall be provided suitable for startup and local or brief operational needs (Insight).
- Ultracapacitor output shall be on board DC or AC voltage / amperage selectable (Insight).
- Prime mover' shall be hydrogen / oxygen EGT / electric motor design to provide thrust and / or drive impellers.
- Motors shall take power from on board high voltage batteries only (Insight).
- On board batteries shall be capable of meeting stand-alone operation for not less than 2 hours of sustained operation (Insight).
- Sustaining H2/O2 EGT combustion will require on-board compressed gaseous supply (Insight).
- Batteries to be LiON or better and capable of sustained operation.
- Regenerative braking systems including dielectric fluid cooling shall be integrated (Insight).
- EGT exhaust heat can be used for environmental control of batteries and indirectly the motors on a pass / bypass basis (Insight).
- Motors must be AC not DC (debate possible) to mitigate resistor heat issues.
- Motors shall use a vaporizable dielectric fluid for heating / cooling both within the powergen system as well as the fuselage.
- Heating / cooling of the fuselage shall be by radiator chilling or EGT heating of the non-hazardous dielectric fluid which may be palm oil or a derivative (Insight).
- On-board hydrogen generation shall be by incident solar reforming (previous – by author) serially mounted on the trailing cars roofs and / or the locomotive (Insight).
- Alternatively, externally supplied compressed hydrogen shall be provided and supplied from an on-board tank of appropriate design.
- On-board oxygen may be supplied from the incident solar reforming system as a product or more preferentially from a PSA supplied concentrated product (Insight).
- Alternatively, hydrogen may be solar reformed from a methane concentrate from a sequentially MOF configured on-board PSA (Insight).

- Said PSA (s) may be single but should be parallel installed for redundancy (Insight).
- External control systems shall be optimized for both on time people and goods delivery at least cost and least risk.
- On board control systems shall include control and use of cooling / heating AC drive motor's dielectric fluid (Insight).
- Air transport fuselage shall be lifting body design optimized for efficiency reflecting least cost, least risk operation.
- Air transport wings' aspect ratio shall be highly variable designed for efficiency reflecting least cost, least risk operation (Insight).
- On board H2/O2 low OPR (LOPR) expanding gas combustion turbine(s) with no visible inlet shall be wing or tail mounted optimized for efficiency reflecting least cost, least risk operation (Insight).
- On board H2/O2 low OPR (LOPR) expanding gas combustion turbine(s) may also have an irised (normally closed) inlet of such diameter and geometry to provide supplemental air for the LOPR for takeoff and other high speed operating regimes (Insight).
- LOPR exhaust to be VTOL/STOL design but reflecting the least cost, least risk design basis it will likely be STOL only (Insight).
- Air transport shall be mixed use (people and freight) transport targeted designs optimized for least cost, least risk operation.
- The air transports' propulsion concept shall be a hybrid turbine / electric concept.
- Take off / landing to be LOPR powered "jet" capable of sustained max thrust for 30+ minutes.
- Cruise to be trailing edge electric turboprop.
- On board batteries and their LOPR EGT power source to be dielectric fluid cooled / heated (Insight).
- During cruise state there will be no cruise heat emissions per se (Insight).
- Max speed will likely be 0.5 mach.
- Nextgen air travel assumes close integration with mixed high-speed rail both meant to mitigate any need for hydrocarbons and still provide superior service and delivery (Insight).
- Cruise range will be nearly unlimited (Insight).
- On board H2/O2 concentration via PSA ala F-35 as a concept but not for cabin / passenger uses (Insight).

- Cruise altitude likely 10 - 15K above MSL and will not need passenger oxygen (Insight).
- Stealthy design with construction materials to be 98%+ composites with wings and other control surfaces to possibly be high tensile fabric (Insight).
- Roller extensible fabric wings and ailerons actuation via CNT composite flexible linear actuators as a key design parameter (Insight).
- Speed or least transit time is not a key operating parameter.
- Uptime, least cost, least risk operation is the key operating parameter.
- All weather, any time operation is another key operating parameter.
- LOPR to be composite / ceramic construction and must be modular of a common size.
- Turboprops to be composite only with low tip speeds.
- Turboprops to be shrouded with winglets.
- Regenerative turboprop shaft rotation using REM's for battery charging (Insight).
- Air transport sizing must be standardized.
- Air freight must be limited to mission critical items only - otherwise HSR transport is required.
- Multi pilot cockpit must be a design standard.
- UAS / UAV variants should be a "stand in" for military needs (Insight).
- Design by materials and function to be MilSpec "stealthy".
- Impeller shrouds ID may be most efficient PSA inlet via micropores (Insight).
- If VTOL or STOL landing strips are not practical, then landing and takeoff can be LOPR / turboprop.
- Regenerative braking must be a design standard.
- Freight / luggage / munitions must be modular sections insertable into a "freight bay" (Insight).
- Munitions may be carousel launched from said module (Insight).

CONCLUSION

This lengthy report attempts to outline what a transmodal freight system will look like in 2040 and beyond. It further attempts to outline why this might be useful and desirable.

Further, this author believes that most people including government do not understand what the impacts of global climate change will be and how catastrophic their societal impacts will be.

Last, this author has spent much time attempting to outline what types of propulsion systems and general specifications will be for the modes of transport used in such a freight system. I do apologize for the length of this report.